Business Cycle Spillovers in the European Union: What is the Message Transmitted to the Core?

Nikolaos Antonakakis[a,b,c,*], Ioannis Chatziantoniou[b], George Filis[d]

[a] *Vienna University of Economics and Business, Department of Economics, Institute for International Economics, Welthandelsplatz 1, 1020, Vienna, Austria.*
[b] *University of Portsmouth, Department of Economics and Finance, Portsmouth Business School, Portland Street, Portsmouth, PO1 3DE, United Kingdom*
[c] *Johannes Kepler University, Department of Economics, Altenberger Strasse 69, 4040 Linz-Auhof, Austria.*
[d] *Bournemouth University, Accounting, Finance and Economics Department, 89 Holdenhurst Road, Bournemouth, Dorset, BH8 8EB, United Kingdom*

Abstract

In this study, we examine business cycle spillovers in the European Union based on the spillover index of Diebold and Yilmaz (2009, 2012) over the period 1977–2014. The results of our analysis reveal that: (i) The total spillover indices are of high magnitude and very responsive to extreme economic events. (ii) The direction and magnitude of spillovers among group members (i.e. Eurozone core, Eurozone periphery, new Euro Area countries and non-EMU countries) is changing overtime. (iii) The Eurozone periphery is the dominant transmitter of shocks followed by the new EA members, whereas the main recipient of shocks is the Eurozone core. (iv) In terms of country specific results, the Eurozone peripheral countries of Spain, Portugal and Greece are the dominant transmitters of business cycle shocks, whereas Czech Republic, Hungary and Poland are the dominant transmitters of shocks from the new EA members. (v) During the Great Recession, the US is at the epicentre of business cycle transmission. (vi) Finally, the widening of the European debt crisis can be explained by business cycle shocks in the whole Eurozone periphery. Thus, appropriate macroprudential stabilisation policies aiming to steer peripheral economies towards growth, away from turbulence and close to recovery, should be formulated.

Keywords: European Union, Business cycle, Spillover, Variance decomposition, Vector autoregression, Impulse response function
JEL codes: C32; E32; F00

1. Introduction

The recent global economic developments have revived the interest on the propagation mechanisms of economic shocks among European countries. The transmission of business

*Corresponding author: e-mail: nikolaos.antonakakis@wu.ac.at, phone: +43 1313364133, fax: +43 131336904133.

cycle shocks among member–states is now becoming of major interest and concern, given that the effects of the debt crisis are still rippling through the European economy. To this end, there is an ongoing discussion concerning the origins of the European debt crisis among member–states. Yet, there is only anecdotal evidence as to which country was responsible for initiating this crisis, as well as, on how shocks are transmitted both within and between European economies.

This research purports to increase our understanding regarding business cycle synchronisation among European countries. In particular, by employing the novel spillover index approach proposed by Diebold and Yilmaz (2009, 2012) this study concentrates on spillover effects generated among business cycles shocks, aiming to shed additional light on issues revolving around the business cycle synchronisation among the EU15 and the EU28 member-countries, as well as, among the EU15, China and the US; the last two, specifically employed in order to capture global effects. This spillover index methodology has already attracted significant attention by the economic literature, investigating issues such as stock market co–movements, volatility spillovers and bond yields spillovers (see, *inter alia*, McMillan and Speight, 2010; Yilmaz, 2010; Bubák et al., 2011; Antonakakis, 2012b; Zhou et al., 2012; Antonakakis and Vergos, 2013).

As will be explained in greater detail below, there are various channels through which spillovers can be generated and affect business cycle synchronisation among countries. To facilitate the discussion, current literature identifies four main channels; that is, the trade channel, the exchange rate channel, the financial integration channel, as well as, the confidence channel (Eickmeier, 2007). It is also worth noting that many authors have so far investigated cyclical synchronisation issues on the basis of these channels (see, inter alia, Canova and Dellas, 1993; Imbs, 2004; Eickmeier, 2007; Imbs, 2010; Claessens et al., 2012). However, little attention has been given to the spillovers which can be generated among business cycles shocks (two exceptions are Yilmaz, 2009; Antonakakis and Badinger, 2014). Yilmaz (2009) applies the spillover index methodology by Diebold and Yilmaz (2009) to seasonally adjusted monthly industrial production series for the G-6 countries over the period 1958–2010 to identify how shocks to industrial production in one country affect the industrial output in other countries. In principle, he maintains that business cycle spillovers can be used to explain business cycle synchronisation, implying that a higher spillover index reflects higher degree of business cycle co–movements. Antonakakis and Badinger (2014) employ the spillover index methodology by Diebold and Yilmaz (2012) on annual data for 27 developed and developing countries over the period 1870–2012, and find that: (i) international business cycle spillovers vary considerably over time. In particular, the authors find a clear increasing trend since the end of World War II and until the mid-1980s. After that, international business cycle interdependencies declined during the period that was dubbed the Great Moderation and stabilized around the beginning of the twenty-first century. During the Great Recession of 2008-2009, international business cycle spillovers increased to unprecedented levels. (iii) Developed countries are consistently ranked as net transmitters of cyclical shocks to developing counties. In this regard, we build on Yilmaz (2009) work and by adopting the Diebold and Yilmaz (2009, 2012) spillover index approach, we investigate both directional and net spillovers, as well as, spillovers across the county groups of EU15, EU28, and China and the US (global effect).

The period of study extends from 1977 to 2014. The chosen period allows the examination of cyclical interdependencies over a span of time where many significant economic events took place, not only in Europe, but also globally (e.g. the financial crisis of 1987, the collapse of the Soviet Union in 1989, the ERM II crisis in 1992, the Asian crisis of 1997, the inception of the EMU in 1999, the Great Recession of 2007-2009, as well as, the ongoing European debt crisis which began in the ending of 2009).

Research on business cycles can be traced back in time to the work of Mitchell (1927), Burns and Mitchell (1946), Kuznets (1958), Mundell (1961) and McKinnon (1963). Investigating the factors that drive fluctuating levels of economic activity, as well as, purporting to decipher the forces that determine the duration of business cycles became a rather promising field of research and gained much prominence especially during the 1990s when it was initially established that output fluctuations in both industrialised and developing countries share many common characteristics (see, *inter alia*, Backus et al., 1993; Gregory and Smith, 1996; Baxter and King, 1999; Lumsdaine and Prasad, 2003; Kose et al., 2003). A thorough description of the relevant literature can be found in Inklaar et al. (2008) and Papageorgiou et al. (2010).

The importance of European business cycle synchronisation lies on the fact that it is a pre-requisite for the smooth and efficient operation of monetary policy within a currency-union. The building blocks of a theory of optimum currency area were laid in the work of Mundell (1961). In his work Mundell (1961) stresses the necessity for one single currency and one central bank responsible for the countries comprising this area and also emphasizes the importance for the area to maintain a flexible exchange rate with the rest of the world. Furthermore, Rogoff (1985), Gertler et al. (1999), Fidrmuc and Korhonen (2006), as well as, Savva et al. (2010), are among others who put forward the argument that unless business cycles within the currency union are synchronised, then asymmetric shocks that will hit each individual economy (or asymmetric individual responses to symmetric shocks) will inevitably lead to predicaments in a uniform monetary policy implementation and to destabilisation.

However, making inferences about economic phenomena is rarely as simple as it initially appears and empirical evidence can at times be contradicting. Thus, the current literature of the European business cycle synchronisation has produced inconclusive findings. In particular, many authors (see, *inter alia*, Fatas, 1997; Angeloni and Dedola, 1999; Belo, 2001; Altavilla, 2004; Weyerstrass et al., 2011) argue that higher levels of synchronisation can indeed be reported early on in the 1990s. Even more, some provide evidence that cyclical interdependencies have increased even further with the establishment of the EMU (see, *inter alia*, Gayer, 2007; Darvas and Szapáry, 2008; Michaelides et al., 2013). De Pace (2013) pertaining to both the globalisation and the currency union effects on business cycle synchronisation, also reports that the establishment of the European Monetary Union (EMU) in 1999 was followed by clear evidence of higher correlations among the business cycles of certain European countries.

Contrary to the exponents of business cycle convergence due to the establishment of currency-union, other authors voice the opinion that what happened in the years that followed the establishment of the EMU was actually quite the opposite. To begin with, Lehwald

(2012) argues that higher levels of cyclical interdependence are a fact only for core European economies rather than for the whole EMU member countries. Along a similar vein, authors such as Hughes Hallett and Richter (2008) and Crespo-Cuaresma and Fernández-Amador (2013a) provide evidence to suggest that since the adoption of the common currency, business cycles among European member–countries have become rather divergent. Lee (2012, 2013) further reports that the degree of synchronisation among European countries was actually higher before the EMU. On a final note regarding the EMU, Canova et al. (2012) in a recent study opine that researchers should be very cautious when linking developments in the behaviour of European cyclical interdependencies to institutional changes in Europe.

A recent strand of the literature examines the effects of the latest financial crisis on synchronisation levels in Europe. Authors such as Gächter et al. (2012) and Gomez et al. (2012) in analysing a group of European countries for the period during and after the Great Recession provide evidence that, since the outbreak of the crisis, the prevailing pattern was the decoupling of business cycles. On top of that, some studies stress the necessity to investigate not only the contemporaneous synchronisation of business cycles but also their lead/lag relationship (see, for instance Darvas and Szapáry, 2008; Gouveia and Correia, 2008; Weyerstrass et al., 2011, among others), which refers to the transmission mechanisms of business cycle shocks. In this regard, empirical research should also turn its focus to spillover effects among business cycles.

Business cycle shocks may be transmitted across economies via four main channels. In short, there is the trade channel, the exchange rate channel, the financial integration channel, as well as, the confidence channel (Eickmeier, 2007). More specifically, the trade channel is explained on the basis of higher exports in one country as a result of higher demand for imports in another country (Canova and Dellas, 1993; Kose and Yi, 2006). According to Clark and van Wincoop (2001) and Calderŏn et al. (2007) this channel is of particular importance to EMU countries, as monetary unions tend to foster trade among their members. Furthermore, Calderŏn et al. (2007) maintain that the positive impacts of trade intensity are better realised when countries exhibit similar production structures. A different perspective is offered by Ng (2010) who puts forward the argument that the effects of trade intensity on business cycle synchronisation are stronger when countries specialise in different stages of the production process. On a final note, Davis and Huang (2011) provide evidence to support the view that changes in the terms of trade (i.e. the relative price of exports in terms of imports) affect countries' business cycles and their synchronisation.

The exchange rate channel, on the other hand, pertains to positive shocks in foreign economies which result in the depreciation of the local currency. Subsequently this could lead to an increase of domestic country's competitiveness and thus to an improvement of the domestic trade balance. On the downside, this depreciation could also result in importing inflation (Eickmeier, 2007).

Turning to the financial integration channel, this can bear both positive and negative spillover effects. In particular, we maintain that financial markets and business cycles are closely related and thus higher level of integration among financial markets could lead to stronger spillover effects among business cycles. This is in line with Claessens et al. (2012) who argue that disturbances in financial markets are associated with bust phases of business cycles. The Great Recession of 2007–2009 is a representative example supporting this argument. Furthermore, financial integration allows for greater capital mobility and in this regard, capital flows from a domestic economy to a foreign economy may very well harm the former and improve output levels in the latter (see, *inter alia,* Canova and Marrinan, 1998; Imbs, 2004). By contrast, Kalemli-Ozcan et al. (2013) show that higher levels of financial integration lead to a decoupling of business cycles.

Finally, the confidence channel reflects the response of domestic agents to potential spillovers deriving from foreign shocks to the local economy. In addition, the strength of the spillover depends on whether agents over- or under-react to (asymmetric) information about foreign shocks (Eickmeier, 2007).

Apparently, despite the fact that many studies have been carried out relating to business cycle synchronisation (see, Artis et al., 2011; Antonakakis, 2012a; Lee, 2012; Crespo-Cuaresma and Fernández-Amador, 2013a,b; Degiannakis et al., 2014, among others) only Yilmaz (2009) explicitly focuses on spillovers among business cycles shocks. Thus, this study adds to this strand of the literature by investigating European business cycle spillovers among EU15 and EU28 member-countries, in a time-varying environment.

The remainder of the paper is organized as follows. Section 2 discusses the application of the spillover index approach and describes the data used. Section 3 presents the empirical findings for the EU15 and EU28. Section 4 focuses on the spillover effects of non–EU countries. Finally, Section 5 summarizes the results and concludes the study.

2. Empirical Methodology and Data

2.1. Spillover methodology

The spillover index approach introduced by Diebold and Yilmaz (2009) builds on the seminal work on VAR models by Sims (1980) and the well-known notion of variance decompositions. It allows an assessment of the contributions of shocks to variables to the forecast error variances of both the respective and the other variables of the model. Using rolling-window estimation, the evolution of spillover effects can be traced over time and illustrated by spillover plots. For the purpose of the present study, we use the variant of the spillover index in Diebold and Yilmaz (2012), which extends and generalizes the method in Diebold and Yilmaz (2009).

Starting point for the analysis is the following P-th order, N-variable VAR

$$y_t = \sum_{i=1}^{P} \Theta_i y_{t-i} + z_t + \varepsilon_t \tag{1}$$

where $y_t = (y_{1t}, y_{2t}, \ldots, y_{Nt})$ is a vector of N endogenous variables, $\Theta_i, i = 1, ..., P$, are $N \times N$ parameter matrices, z_t is an exogenous variable capturing global shocks (in our case the index of general real economic activity developed by Kilian, 2009) that may affect all countries simultaneously.[1] $\varepsilon_t \sim (0, \Sigma)$ is vector of disturbances that are independently distributed over time; $t = 1$, ..., T is the time index and $n = 1$, ..., N is the variable index.

[1]The index of global real economic activity (GEA) in industrial commodity markets has been extracted from Lutz Kilian's website at: `http://www-personal.umich.edu/~lkilian/paperlinks.html`

Key to the dynamics of the system is the moving average representation of model (1), which is given by $y_t = \sum_{j=0}^{\infty} A_j \varepsilon_{t-j}$, where the $N \times N$ coefficient matrices A_j are recursively defined as $A_j = \Theta_1 A_{j-1} + \Theta_2 A_{j-2} + \ldots + \Theta_p A_{j-p}$, where A_0 is the $N \times N$ identity matrix and $A_j = 0$ for $j < 0$.

Following Diebold and Yilmaz (2012) we use the generalized VAR framework of Koop et al. (1996) and Pesaran and Shin (1998), which produces variance decompositions invariant to the variable ordering. According to this framework, the H-step-ahead forecast error variance decomposition is

$$\phi_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \tag{2}$$

where Σ is the (estimated) variance matrix of the error vector ε, σ_{jj} the (estimated) standard deviation of the error term for the j-th equation and e_i a selection vector with one as the i-th element and zeros otherwise. This yields a $N \times N$ matrix $\phi(H) = [\phi_{ij}(H)]_{i,j=1,\ldots N}$, where each entry gives the contribution of variable j to the forecast error variance of variable i. The main diagonal elements contain the (own) contributions of shocks to the variable i to its own forecast error variance, the off-diagonal elements show the (cross) contributions of the other variables j to the forecast error variance of variable i.

Since the own– and cross–variable variance contribution shares do not sum to one under the generalized decomposition, i.e., $\sum_{j=1}^{N} \phi_{ij}(H) \neq 1$, each entry of the variance decomposition matrix is normalized by its row sum, such that

$$\tilde{\phi}_{ij}(H) = \frac{\phi_{ij}(H)}{\sum_{j=1}^{N} \phi_{ij}(H)} \tag{3}$$

with $\sum_{j=1}^{N} \tilde{\phi}_{ij}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\phi}_{ij}(H) = N$ by construction.

This ultimately allows to define a total (volatility) spillover index, which is given by

$$TS(H) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}_{ij}(H)}{N} \times 100 \tag{4}$$

which gives the average contribution of spillovers from shocks to all (other) variables to the total forecast error variance.

This approach is quite flexible and allows to obtain a more differentiated picture by considering directional spillovers: Specifically, the directional spillovers received by variable i from all other variables j are defined as

$$DS_{i\leftarrow j}(H) = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\phi}_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ij}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\phi}_{ij}(H)}{N} \times 100 \tag{5}$$

and the directional spillovers transmitted by variable i to all other variables j as

$$DS_{i\rightarrow j}(H) = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\phi}_{ji}(H)}{\sum_{i,j=1}^{N} \tilde{\phi}_{ji}(H)} \times 100 = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\phi}_{ji}(H)}{N} \times 100. \tag{6}$$

Notice that the set of directional spillovers provides a decomposition of total spillovers into those coming from (or to) a particular source.

By subtracting Equation (5) from Equation (6) the net spillovers from variable i to all other variables j are obtained as

$$NS_i(H) = DS_{i \to j}(H) - DS_{i \leftarrow j}(H), \tag{7}$$

providing information on whether a country (variable) is a receiver or transmitter of shocks in net terms. Put differently, Equation (7) provides summary information about how much each variable contributes to the volatility in other variables, in net terms.

The spillover index approach provides measures of the intensity of interdependence across countries and variables and allows a decomposition of spillover effects by source and recipient.

2.2. Data description

We collect monthly observations of industrial production as a proxy measure for economic activity for each of the EU28 countries, as well as the US and China. Data availability and sources are provided in Table A.1 in the Appendix.

All series are seasonally adjusted. Given that we are interested in business cycles interdependencies, we use the Hodrick-Prescott (HP) filtered series of the natural logarithm of seasonally adjusted industrial production series (with a smoothing parameter of 129,600), as this is the most common indicator of business cycles.[2]

[Insert Table 1 here]

Table 1 reports the descriptive statistics of the business cycle series for each country. As far as European countries are concerned, business cycles of higher magnitude can be observed mainly for new EU countries such as Estonia, Latvia, Lithuania and Slovakia, but also for older members such as Ireland and Sweden. By contrast, business cycles of lower magnitude can be observed for France, the Netherlands, Slovenia, Spain and the UK. Turning our attention to sample countries outside Europe, we notice that China exhibits cycles of greater magnitude compared to those of the US. Most series are leptokurtic and exhibit negative skewness with the exception of the series regarding Cyprus, Croatia and Malta (platykurtic), as well as, China and Ireland which are positively skewed. The negative skewness indicates that bust phases of business cycles have a higher magnitude compared to boom phases. Especially for European countries, this could potentially be attributed to the effect of the two latest Euro Area (EA) recessions. Furthermore, all series apart from the one concerning Portugal reveal non–normality. Finally, according to the ADF–test statistic, all cycles are stationary.

[2] However, we have explored the robustness of our empirical findings by employing alternative measures of business cycles, such as the band pass filter and the 12-difference growth rates of industrial productions, and our results described below remain qualitatively similar.

3. Empirical findings

In this section we present the results from our empirical analysis, starting with the estimates of the spillover index and its subindices, defined in Equations (4)-(7). We then consider the time-varying nature of spillovers indices.

3.1. EU15

3.1.1. Spillover Indices

Table 2 presents the results of the spillover indices based on 24-month ahead forecast error variance decompositions. Before discussing the results, however, we shall first describe the elements of the table. The $ij-$th entry in Table 2 is the estimated contribution *to* the forecast error variance of variable i coming *from* innovations to variable j (see Equation (2)). Note that each variable is associated with one of the EU15 business cycles. Hence, the diagonal elements ($i = j$) measure own–country spillovers of business cycles, while the off–diagonal elements ($i \neq j$) capture cross–country spillovers of business cycles. In addition, the row sums excluding the main diagonal elements (labeled 'Directional from others', see Equation (5)) and the column sums (labeled 'Directional to others', see Equation (6)) report the total volatility spillovers 'to' (received by) and 'from' (transmitted by) each variable. The difference between each (off-diagonal) column sum and each row sum gives the net spillovers from variable i to all other variables j (see Equation (7)). The total volatility spillover index defined in Equation (4), given in the lower right corner of Table 2, is approximately equal to the grand off-diagonal column sum (or row sum) relative to the grand column sum including diagonals (or row sum including diagonals), expressed in percentage points.[3]

[Insert Table 2 here]

Several interesting results emerge from Table 2. First, own–country business cycle spillovers explain the highest share of forecast error variance, as the diagonal elements receive higher values compared to the off-diagonal elements. For example, innovations to business cycles in Greece explain 73.63% of the 24-month forecast error variance of business cycles in Greece, while only 0.30% in Germany and 0.92% in France. However, innovations to business cycles in Germany explain 28.43% of the 24-month forecast error variance of business cycles in Germany, while only 1.23% in Greece and 8.81% in France. In this regard, the preliminary evidence shows that shocks originating from the Greek economy tend to be contained within the Greek borders.

Second, Spain is the dominant transmitter of business cycle shocks followed by the UK and Luxembourg, while Austria, Belgium, Denmark, Finland, Portugal and Ireland are dominant receivers of business cycles shocks. These results are supported by the 'directional to others' row and the 'directional from others' column in Table 2. They are also supported by the net directional spillovers values, which measure the net spillovers from country i to

[3]The approximate nature of the claim stems from the fact that the contributions of the variables in the variance decompositions do not sum to one and have to be normalized (see Equation (3)).

all other economies j, reported in the last column of Table 2. Specifically, Spain is the dominant country in business cycle transmission with a net spillover of 168.78%[4] to all other countries' business cycles followed by UK (73.33%), Luxembourg (40.27%), Germany (5.22%) and France (4.17%), while Austria is the dominant net receiver of business cycle shocks (-64.77%) from all other countries' business cycles with a net spillover, followed by Belgium (-49.85%), Finland (-37.68%), Denmark (-33.81%), Portugal (-25.01%), the Netherlands (-20.15%), Ireland (-20.07%), Italy (-18.19%), Greece (-13.99%) and Sweden (-7.26%). These results are of great importance as, for instance, business cycle shocks in any individual EU15 country may have certain repercussions for other countries and thus, it can be a good indicator of future changes in their business cycles.

Third, and most importantly, according to the total spillover index reported at the lower right corner of Table 2, which effectively distils the various directional spillovers into one single index, on average, 53.96% of the forecast error variance in EU15 countries' business cycles comes from spillovers of shocks across countries, while the remainder can be explained by own-country shocks.

In summary, the results reported in Table 2 suggest that, on average, both the total and directional spillovers of business cycles within the EU15 countries were extremely high during our sample period, denoting the high level of business cycle interdependencies.[5]

3.1.2. Spillover Plots

While the use of an average measure of business cycle spillovers provides a good indication of business cycle transmission mechanism, it might mask interesting information on movements in spillovers due to secular features of business cycles. Hence, we estimate the model in Equation (1) using 60-month rolling windows and obtain the variance decompositions and spillover indices.[6] As a result, we obtain time-varying estimates of spillover indices, allowing us to assess the intertemporal evolution of total and directional business cycle spillovers within and between EU15 countries.

[Insert Figure 1 here]

Figure 1 presents the results for the time-varying total spillover index obtained from the 60-month rolling windows estimation. Large variability in the total spillover index is, indeed, present and the index is very responsive to extreme economic events. For instance, the total spillover index reaches a peak during Euro Area (EA) recessions, e.g. during the 1980s, 1992–1993, 2008–2009, as well as, at the onset of the Great Recession of 2007–2009. Furthermore, the index follows a decreasing trend starting at the mid-1980s and reaches a minimum just before the ERM II 1992 crisis. The road to the introduction of the Euro

[4]Note that according to the generalised spillover index approach of Diebold and Yilmaz (2012), directional and net spillovers do not sum to 100%.

[5]We have explored the robustness of our results using alternative n–month ahead forecast error variance decompositions (12, 36 and 48 months) and the results remain qualitatively similar.

[6]Our results reported below remain robust to alternative choices of window length (i.e. 36, 48 and 72 months).

starts with a short-lived decline in spillovers between 1997 and 2001, and then follows an increasing trend since the inception of the common currency. During the Great Recession, business cycle spillovers reach unprecedented levels. In turn, the ongoing European debt crisis withheld business cycle spillovers at very high levels; however, since 2013 a reversal is observed with the spillover effects exhibiting a significant decrease. This may suggest that EU15 countries gradually adapt to ongoing unstable conditions and spillover effects are therefore somewhat anticipated. Overall, these results indicate that during economic downturns, interdependencies across countries tend to increase significantly and are in line with previous studies (Imbs, 2010; Yetman, 2011; Antonakakis, 2012a).

Despite results for the total spillover index being informative, they might discard directional information that is contained in the "Directional to others" row (Equation (5)) and the "Directional from others" column (Equation (6)) in Table 2. Figure 2 presents the estimated 60-month rolling windows directional spillovers from each of the business cycles to others (corresponding to the "Directional to others" row in Table 2), while Figure 3 presents the estimated 60-month rolling windows directional spillovers from the others to each of the business cycles (corresponding to the "Directional from others" column in Table 2).

[Insert Figure 2 here]

[Insert Figure 3 here]

According to these two figures, the bidirectional nature of business cycle spillovers between the EU15 countries is evident. Nevertheless, they behave rather heterogeneously over time. Specifically, according to Figure 2, only in the case of Spain directional spillovers from business cycles exceed the 35% level during the EA recession of 2008–2009. Other than that, directional spillovers from or to each business cycle range between 5%–30%. Interestingly enough, the directional spillovers deriving from all other EU economies to each individual business cycle appear to remain constant over time at a level of 7% for all countries. This is suggestive of the fact that business cycle shocks are spread evenly across individual countries.

A similar picture emerges when looking at the net directional spillover indices obtained from the 60-month rolling window estimation. According to Figure 4, which plots the time-varying net directional spillovers, we see that Ireland, Spain and the UK are mostly net transmitters of business cycles shocks during the sample period, while Austria, Belgium, Denmark, Finland, France, Italy and Portugal are mainly at the receiving ends of net business cycle transmissions. The picture is mixed for Greece, Germany, Luxembourg, the Netherlands and Sweden. Nevertheless, Greece appears to be a significant net transmitter during the period just before the introduction of the Euro (possibly due the uncertainty surrounding the country's non compliance with the convergence criteria laid out in the Maastricht Treaty) and prior and during the EA recession of 2008–2009. Interestingly, Greece is a transmitter of business cycle shocks in the period before the European debt crisis, although it maintains its net transmitting role in the first few months of the Eurozone debt crisis (however, at a lesser extent). By contrast, during the European debt crisis, it is rather Spain, Ireland and Italy that are transmitting business cycle shocks.

Overall, the findings suggest that the amplification of business cycle shocks across the EU15, during the latest global financial crisis, may very well be attributed to Eurozone peripheral countries and in particular to countries such as Spain, Ireland and Italy.

[Insert Figure 4 here]

3.1.3. Net Spillover Indices among Groups of Countries

To examine further the net spillover effects among the EU15 countries, we turn our attention to net spillover effects among groups of countries, namely Eurozone core countries, Eurozone peripheral countries and non-EMU countries. Figure 5 illustrates these net spillovers among the three groups.

[Insert Figure 5 here]

In principle, net spillovers tend to be of great magnitude between the core and peripheral Eurozone countries, followed by those between the core and non-EMU countries. The lowest magnitude of net spillovers is observed between the peripheral and non-EMU countries.

Starting with net spillovers among core and peripheral countries we observe that both groups can either be net transmitters or net receivers of business cycles shocks at different time periods. In particular, during the period between the late 80s and the early 90s (i.e. the ERM II period), as well as, in the years that followed the introduction of the euro currency, core countries can be credited with transmitting business cycles shocks to the Eurozone periphery. By contrast, during the years that followed the collapse of ERM II and until the introduction of the euro, as well as, the post-2007 period (which is characterised by two EA recessions and the Great Recession of 2007–2009) peripheral countries were, in general, the main transmitters of business cycles shocks to the core countries.

Possibly the dynamic change in the nature of each group (i.e. net transmitter or net receiver) can be explained by the transmission channel of business cycles shocks. More specifically, the fact that core countries are the main transmitters during the ERM II period may be explained by the dominant character of the German economy and by the fact that all other countries pegged their currency to the Deutsche Mark and thus followed the German monetary policy (see, for instance, Degiannakis et al., 2014). Turning to the Maastricht Treaty period, the effort put by peripheral economies to meet the convergence criteria and thus qualify to member EMU states, serves as a plausible explanation as to why peripheral countries are the net transmitters of the period.

The following period; that is, the period after the adoption of the common currency and until 2007, core countries become net transmitters and this could be explained on the basis of increased structural funding, mainly provided by the core European members, in order for the European periphery to overcome structural deficiencies and strengthen their economy. Furthermore, results for the later period of our study (i.e. the post–2007 period), when peripheral countries become net transmitters comes as no surprise, given that the GIIPS (i.e. Greece, Ireland, Italy, Portugal and Spain) were heavily affected by the economic turbulence during the aforementioned period. In particular, following the Great Recession, many Eurozone peripheral countries experienced a deterioration in their government finances in late 2009, that led to debt sustainability concerns in these countries. This, in turn, led to financial market pressure and anxiety over a series of potential defaults and contagion to other Eurozone countries.

Turning to the net spillovers between core and non-EMU countries, we observe that the former countries are the main transmitters, apart from the period 2011–2012 when non-EMU countries become net transmitters of business cycles shocks. This could potentially be attributed to economic conditions in the UK. Similarly, the main net transmitters between peripheral and non-EMU countries are the former countries. It is worth noting that the magnitude of net spillover effects is higher during the last two EU recessions, as well as, in the period between them.

3.1.4. Cumulative Generalised Impulse Response Functions

We further our analysis by providing a summary picture of the bottom line effect of business cycle shocks. To achieve that, we calculate for each country the cumulative effects of a one–standard deviation shock to business cycle on the respective country's business cycle, referred to as 'within–country' response, and the cumulative effects of a one–standard deviation shock to business cycle on the other country's business cycle, referred to as 'between–country' response.[7] Table 3 reports the averages of the cumulative effects i) of business cycle shocks on within–country business cycle, and ii) of business cycle shocks on between–country, for the full sample period and for each group of countries (Eurozone core, Eurozone periphery and non–EMU). The cumulative effects are reported for time horizons of 12, 24, 36 and 48 months. As the effects of business cycle shocks have fully materialized after 4 years, the cumulative 48–month responses can be interpreted as overall bottom line effects of incipient shocks including spillover effects and the associated repercussions.

[Insert Table 3 here]

Overall, all shocks have positive and multiplicative effects suggesting a positive (negative) shock in a country leads to a positive (negative) response in other countries. In terms of the within–country effects, we observe fairly low and of similar magnitude cumulative responses for all three groups. In particular, the within–periphery responses amount to 5.097% followed by those of within–non–EMU (4.335%) and within–core (3.663%). Of particular interest are the cumulative response effects between–countries. First, own group shocks matter less than cross group shocks for the Eurozone core and periphery, whereas the reverse holds true for the non-EMU countries. Put differently, the core and periphery responses are more sizeable to other group shocks as opposed to own group shocks. For instance, the response of core countries business cycles to shocks originating in the core are lower (6.464%) compared to their responses to shocks originating in the periphery (20.495%) and non–EMU countries (9.539%). A similar pattern is also observed in the periphery where the largest in magnitude

[7]Notice that with a stationary VAR the cumulative effects of one–time business cycle shock have to be interpreted as level effects and should not be confused with permanent effects on the business cycle.

cumulative response effects is observed for the non–EMU to shocks (13.678%), while the lowest are the responses to Eurozone core shocks (6.458%). Third, a somewhat different picture is observed for the non–EMU countries, where the magnitude of their responses to own–group shocks is very high (15.348%), followed by the responses to the periphery (5.346%) and core countries (1.370%) shocks. Overall, it is evident that the Eurozone core countries are showing to be affected significantly by shocks originating from other groups. In addition, the non-EMU shocks seem to be of high importance to the periphery.

3.2. EU28

3.2.1. Spillover Indices

In recent years, the EU has been considerably enlarged to 28 countries with Croatia being the most recent country to become a member state in 2013. It is worth noting that most of the new accessions involve Eastern European Industrialising Economies (EEIE) while Cyprus and Malta are the only new member states with a stronger focus on the tertiary sector of the economy. From an empirical point of view it would be instructive to investigate spillover effects among this enlarged group of 28 countries in order to assert whether the accession of new members entails different outcomes regarding the net transmitting/receiving role of each one of the sample countries. To refrain from unnecessary repetition of certain results, analysis in this section mainly focuses on the new member states, aiming to identify specific differences - if any - between the EU15 and the EU28 group of countries.

[Insert Table 4 here]

Table 4 reveals that as in the EU15 case, shocks originating within each EU28 economy tend to be contained within the borders of each country (i.e. the main diagonal elements of Table 4 receive higher values compared to off-diagonal elements). However, the inclusion of the new EU countries results in a considerably higher total spillover index. In particular, considering a full sample of EU28 counties, then on average, 79.36% of the forecast error variance in all 28 countries relates to spillover effects of shocks across countries. In the interests of comparison, the total spillover index for EU15 is 53.55% (see Table 2). What is more, Spain remains the dominant transmitter (in both total and net terms) of business cycle shocks for our extended sample of countries. However, considering net business cycle spillovers for the EU28, we observe that contrary to their previous state, both Luxembourg and the UK act as net recipients of spillover effects while Italy as a net transmitter. It should also be noted that Estonia, Poland, as well as, the Czech Republic are the only three new EU countries which exhibit a net transmitting character. Nonetheless, before we attempt to interpret these findings and also in order to be consistent with our previous analysis it would be instructive at this point to proceed with presenting the results of the dynamic spillover effects among the EU28.

3.2.2. Spillover Plots

Figure 6 illustrates the dynamic evolution of the total spillover index obtained from a 60-month rolling windows estimation. Considering a smaller sample due to data availability constraints, we notice that the EU28 total spillover index appears to be responsive to extreme economic events. In particular, we observe a clear spike during the peak years of the Great Recession, while from then onwards there is an upward trend mainly reflecting the turbulent period associated with the European Debt Crisis. Apparently, there appears to be a decreasing trend in very recent years; however, the value of the index remains at relatively high levels.

[Insert Figure 6 here]

Turning to directional spillover effects among EU28 countries, Figures 7 and 8 reveals that these spillovers behave rather heterogeneously over time.

[Insert Figure 7 here]

[Insert Figure 8 here]

As in the EU15 case, Spain obviously remains the dominant transmitter of business cycle shocks during the years of the EA recession of 2008–2009 with a level of spillovers in the region of 25% (see Figure 7). In more recent years, marked by the ongoing European Debt Crisis, again we note the key role of Spain in transmitting business cycles shocks to all other countries. In addition, we cannot discard the transmitting role of Austria and Italy, especially in the beginning of the European Debt Crisis, as well as, the magnitude of business cycles shocks originating in new EU members such as the Czech Republic, Hungary and Poland. Shocks originating in Greece and Portugal on the other hand, appear to make their presence noticed only in the very recent years of our sample, without in fact reaching the quite extreme levels that might be expected for these two countries. Figure 8 is also quite informative in that it enlightens us about the allocation of business cycle shocks across the EU28 countries. From the spillovers depicted on Figure 8 it is obvious that business cycle shocks are evenly spread across countries and that their level remains rather constant across time; i.e. on the order of 5%.

In order to attain a better understanding of the underlying interdependencies it would be useful to concentrate on net spillover effects (Figure 9). Concentrating on the European Debt Crisis which started on the eve of 2009, we notice that all of the countries previously reported to exhibit a high level of directional spillovers are in fact net transmitters of these shocks. In particular, we underscore the key net transmitting role of countries such as Spain, Austria and Italy (i.e. especially in the beginning of the European Debt Crisis), Greece and Portugal (i.e. especially in more recent years), as well as, the Czech Republic, Hungary and Poland (i.e. new EU members).

[Insert Figure 9 here]

In order to increase our understanding regarding the underlying interrelations between the various groups of countries included in this study, we proceed with the investigation of pairwise net spillover effects. Figure 10 reveals that core European countries are net recipients of spillover effects originating in peripheral countries such as Spain, Portugal and Greece for almost the entire period since the beginning of the European Debt Crisis in early 2009. This result accords with previously reported findings regarding the EU15.

[Insert Figure 10 here]

What is also evident in Figure 10 is that new Euro Area members especially EEIE also transmit spillover effects to core European countries. With reference to this particular finding, it is worth noting that the main contributors of spillover effects - deriving from EEIE - are the Czech Republic, Poland and Hungary. This finding is not surprising considering the fact that all these countries (together with Slovakia and Slovenia) are in a relatively better position by virtue of both development (i.e. foreign direct investments) and degree of transition to a market–led system, compared to other industrialising countries in the same geographical region (see, Carstensen and Toubal, 2004; Caporale et al., 2012, among others). Growth in these countries can also be reflected upon the level of capitalisation of their stock market. In particular, Caporale and Spagnolo (2011) report that the Czech Republic, Hungary and Poland exhibit the highest market capitalisation compared to other Central and Eastern European countries. In this regard, our findings further highlight the importance of these countries in the region.

In order to attain a deeper understanding regarding the net transmitting role of EEIE when paired with core European countries, it would be rather instructive to identify potential strong links between these two groups of countries. According to Arezki et al. (2011) many core European countries such as Austria, France, Germany and the Netherlands have very strong financial linkages with Eastern European countries; a fact which renders the former rather vulnerable to either positive or negative developments in the latter. According to Caporale et al. (2012) early on in the 1990s many foreign banks became involved in a process of holding majority shares in the banking sector of EEIE such as the Czech Republic, Hungary, Poland, Slovakia and Slovenia; a fact which proved to be beneficial not only for the financial sector but also for the broader economy of these industrialising economies. What is more, Caporale and Spagnolo (2011) report that foreign investments in the aforementioned group of EEIE have also been strongly supported by the fact that during the 1990s the outbreak of financial crises in other developing countries of the world (e.g. Latin America) resulted in a substantial increase of foreign investments in this particular group of EEIE.

A final point which emphasizes the connection between EEIE and core European countries can be found in the work of Marin (2006) and Marin and Verdier (2014) who put forward the argument that developed economies such as Germany and Austria invest heartily in EEIE in order to benefit from the relatively low labour cost. It follows that at times of recession declining economic activity in industrialising countries may very well affect income in the outsourcing countries.

Turning our attention the remaining results illustrated in Figure 10, we notice that non-EMU countries receive spillover effects from all other group of countries (i.e. new-EA, peripheral and core European countries). This finding could be an indication of further links between these groups of countries. Finally, peripheral countries appear to transmit shocks to new-EA countries rather persistently in recent years a finding which emphasises the fact that there are also links between these two groups of countries.

3.2.3. Cumulative Generalised Impulse Response Functions

Our analysis continues with the examination of the bottom effect of business cycle shocks, as in Section 3.1.4. We examine both the 'within–country' responses (i.e. the cumulative effects of a one–standard deviation shock to business cycle on the respective country's business cycle), as well as, the 'between–country' responses (i.e. the cumulative effects of a one–standard deviation shock to business cycle on the other country's business cycle). In Table 5 we report the average cumulative effects of i) business cycle shocks on within–country business cycle and ii) business cycle shocks on between–country. The figures correspond to the full sample period. In this section we group our sample countries as Eurozone core, Eurozone periphery, Non–EMU and New–EA members). As previously, the cumulative effects are reported for time horizons of 12, 24, 36 and 48 months, with the 48–month responses to be considered as the overall bottom line effects.

[Insert Table 5 here]

As expected, all shocks have positive effects suggesting a positive (negative) shock in a country leads to a positive (negative) response in other countries. Focusing on the 48–month responses, we observe that, on the whole, the within–country effects are considerably lower compared to the between–country effects. Furthermore, we notice that magnitude of cumulative within–responses is somewhat different for the different groups, with the highest value to recorded for the Eurozone periphery (9.873%), followed by the eurozone core (6.946%). On the other hand, the within–country effects for the Non–EMU countries are fairly low (3.374%) and the same holds for the New–EA members (5.452%).

Turning to the between–country effects, which are the most important, we notice that the magnitude of the responses is greater for the shocks originating from the Eurozone periphery and the New–EA members. This is an important findings which complement the analysis of the EU15 member countries. More specifically, it clearly demonstrates the significance of both the peripheral Eurozone economies, as well as, the economies of the New–EA members to the stability of the European countries business cycles. More specifically, we observe that the magnitude of responses from all groups to periphery shocks are above the level of 20%. The highest magnitude is reported from the core countries (28.190%), whereas the lowest from the Non–EMU countries (22.978%). As aforementioned, shocks to the New–EA members business cycles are also of high importance, with the responses from the country groups to range between 6.371% (from the Non–EMU) to 11.990% (from the periphery). The lowest responses are reported from the New–EA countries to shocks originating from the Non–EMU group (0.439%). These results complement the findings reported in Section 3.1.4, as they show that apart from the importance of the Eurozone periphery, it is also the New–EA members which are important transmitters of business cycle shocks.

4. The effects of non–EU countries

So far, our analysis has been confined to business cycles spillovers effects within the EU. That is, without taking into account the influence of business cycles spillovers from/to other major non European countries, such as, the United States and China. Besides, there is empirical evidence of increased international business cycle spillovers during the last two decades (see, for instance, Antonakakis and Badinger, 2014, among others.). Therefore, to control for such effects, as well as for robustness purposes, we repeat our business cycle spillover analysis in the EU15 with the United States and China included.[8]

4.1. Spillover Indices

Table 6 presents the results of the spillover indices in the EU15 countries, the United States and China, based on 24-month step-ahead forecast error variance decompositions.

[Insert Table 6 here]

According to this table, we can observe the following empirical regularities. First, among the two non-European countries, the United States plays a very important role in the transmission process of business cycles in almost all European countries, whereas China's influence is less pronounced. For instance, on the one hand, innovations to business cycles in the United States explain 26.20%, 21.82%, 17.58% and 14.10% of the 24-steap-ahead forecast error variance of business cycles in the UK, Finland, Italy and Spain, respectively. On the other hand, innovations to business cycles in China, explain, at best, 3.02% and 2.67% of the 24-step-ahead forecast error variance of business cycles in the United States and Sweden, respectively. Second, Spain is still the dominant transmitter of business cycles shocks in net terms (even after controlling for business cycle influences from/to other major non-EU countries), followed by the United States, France, Luxembourg, and China. The rest of the countries in the sample are on the net receiving ends of business cycle spillovers. These results are supported by the 'net spillovers' in the last row of Table 6. Third, the total spillover index presented at the lower right corner of Table 6, suggests that 59.28% of the forecast error variance in the EU15 countries, the United States and China's business cycles comes from spillovers across countries. This total spillover index is very similar to that in the EU15 group without the influence of non-EU countries (see Table 1).

Overall, the results of Table 6 indicate that the United States plays an important role in the transmission process of business cycle spillover in the EU15.

---

[8]We have also performed the same analysis for the EU28 countries, with the United States and China also included, and the results, which are available upon request, do not change. However, in the case of the EU15 countries, the United States and China group, the availability of the time sample, and thus the rolling window analysis, is more extended (from 1990M1 to 2014M2) compared to that in the EU28 countries, the United States and China group (from 2000M1 to 2014M2). Thus we present only the results for the EU15 countries, the United States and China group for more completeness in our discussion.

4.2. Spillover Plots

In an attempt to examine whether the effects of business cycle spillovers between the EU15 countries and the United States and China vary over time, we proceed with the rolling window analysis.

Figure 11 presents the time-varying total spillover index based on 60–month rolling windows in the EU15 countries, the United States and China. As in the case of the EU15 countries (see Figure 1), the total spillover index in the EU15 with the United States and China included exhibits similar patterns. That is, large variability is present overtime and total spillovers reach a peak during periods of extreme economic activity, such as, the Asian crisis, the inception of EMU and especially during the Great Recession.

[Insert Figure 11 here]

Turning our attention to the time-varying directional spillovers 'from' and 'to' each of the EU15 countries, the Unites States and China that are presented in Figures 12 and 13, respectively, we observe some interesting patterns. According to Figure 12, the United States is at the epicentre of business cycle spillovers to the EU15 countries and China during global financial crisis that originated in the Unites States and led to the Great Recession and the collapse of manufacturing worldwide, including Europe (Economist, 2009). During that period, directional business cycle spillovers from the Unites States to the rest of the countries in the sample reached unprecedented levels (approximately 50%), becoming twice as high than those originating from Spain (around 25%). After that period, and during the European debt crisis, directional spillovers originating from Spain, China, and to a lesser extent, from Italy and Portugal, become more pronounced. As in the EU15 group (Figure 3), directional spillovers to each individual EU15 countries and the United States and China from all others, presented in Figure 13, appear relatively constant overtime at a level of 5%; thus suggesting that business cycle shocks are equally spread across countries.

[Insert Figure 12 here]

[Insert Figure 13 here]

The time-varying net spillovers of business cycle shocks presented in Figure 14, suggest that, since the Great recession, the United States and Spain were on the net transmitting ends of business cycles shocks. China joined the group of the net transmitters of business cycles shocks in 2010, followed by Italy and Portugal in 2011 (during the European debt crisis). Germany was a net transmitter of business cycle shocks until the beginning of the Great Recession, and a net receiver of business cycle shocks after that. The changing pattern (from net transmitter to net receiver) of business cycle shocks in Germany, could be attributed to the increased uncertainty in the manufacturing sector due to a reduction of foreign investment following investors' concerns/anxiety about debt sustainability in the Eurozone peripheral countries.

[Insert Figure 14 here]

Finally, in Figure 15, we provide a summary of the time-varying spillover effects of business cycles among the following four groups: (i) Eurozone core, (ii) Eurozone periphery, (iii) non-EMU countries and (iv) the United States and China (named as World, henceforth). According to this figure, net spillovers among the core and peripheral countries, and among the core and the world, are more pronounced than those in the remaining pairs. Moreover, net spillovers behave rather heterogenously overtime. The core countries are net transmitters of business cycles shocks to non-EMU throughout the sample, while to the World only until the beginning of the Great Recession, and to the peripheral countries between 2000 and 2008. During the Great Recession, the core countries become net receivers of business cycles shocks from the World and the peripheral countries, while peripheral and non-EMU countries become net receivers of business cycle shocks from non-EU/World countries.

[Insert Figure 15 here]

4.3. Cumulative Generalised Impulse Response Functions

We finalize our analysis with the examination of the bottom effects of business cycle shocks as in Sections 3.1.4 and 3.2.3. Although this time we also focus on the responses to shocks from and to the World business cycle group (i.e. from China and the US), in addition to those from and to the Eurozone core, Eurozone periphery and Non-EMU groups. Table 7 reports the average cumulative effects of i) business cycle shocks on within–groups and ii) business cycle shocks on between–groups.

[Insert Table 7 here]

In terms of the within–groups and between–groups responses among the core, periphery and Non–EMU groups of countries we do not observe any notable difference between Tables 7 and 3. Focusing on the World group it is interesting to notice the very high level of within–country responses (13.215%) suggesting that own country shocks are important to the respective economies.

Turning to the between–groups responses, it is clear that the World group is significantly influencing the Non–EMU countries, given the size of their responses (36.762%), as well as, the Eurozone periphery (9.224%). Nevertheless, the core is also impacted, although to a lesser extent (4.599%). On the other hand, the World group does not seem to respond at a very high degree to shocks originating from the European groups. More specifically, the magnitude of the World responses to shocks originating from the Eurozone core and periphery are at about the same level (4.465% and 4.250%, respectively), whereas they are significantly smaller to shocks from the Non–EMU countries (2.173%). Overall, these findings depict the importance of the Chinese and the US business cycles shocks to the European economy and complement the findings from the spillover effects, which showed the same picture.

As a robustness analysis, we repeated the estimations for each of the 3 groupings (i.e. EU15, EU28 and EU15, US and China) with the use of alternative rolling-window samples. In particular, we experimented with 72-month (6-year) and 84-month (7-year) rolling windows, in addition to 60-month (5-year) rolling-windows, and our results remain unchanged.

For instance, Table A.1 in the Appendix, presents the minimum and maximum values of the total spillovers of business cycles for each of the 3 groupings based on the aforementioned alternative rolling-window samples. According to this table, business cycle spillovers reach unprecedented heights during the Great Recession, and remain at high levels during the ongoing European debt crisis. Overall, these results are in line with our main findings.

5. Conclusions

In this study we investigate the evolution of business cycle spillover effects in EU15 and EU28 countries over the period 1977–2014. We also control for the influence of global business cycle spillover effects. This study contributes to the understanding of the relationship among European business cycles fluctuations. Monthly industrial production observations are considered to be a proxy for countries' GDP, while their cyclical components are extracted from the HP filter.

Our main findings can be summarised, as follows. According to the total spillover index, 53.96% of the forecast error variance in all EU15 countries' business cycles can be explained by cross–country spillovers. For the EU28 and the EU15–world cases, the total spillover indices are 79.36% and 59.28%, respectively. Furthermore, we find that the indices exhibit large dynamic variability while they can be very responsive to economic events, such as downturns of economic activity.

Based on our time-varying analysis, prominent among our findings, is that directional spillover effects originating from Spain are the most pronounced when considering the EU15 and EU28 cases. By contrast, in the case of EU15–world grouping, we find that the United States is in the epicentre of spillover effects, especially during the Great Recession of 2007–2008. That aside, most business cycles shocks are evenly spread across all other individual countries.

However, if we turn our focus to the recent European debt crisis, it appears that it is mostly the peripheral Eurozone countries which are the dominant transmitters of business cycle shocks among the EU15 countries, whereas in the case of EU28, we observe that apart from the peripheral Eurozone countries, they are the new-EA countries that are dominant transmitters of shocks. Put differently, the core Eurozone countries are on the receiving ends of business cycle shocks during the European debt crisis.

As far as core Eurozone countries, peripheral Eurozone countries, new–EA and non–EMU countries are concerned, net spillovers tend to be of greater magnitude between core and peripheral Eurozone countries, as well as, core and new–EA countries. In addition, evidence suggests that the net transmitting or net receiving character of each group of countries is time–specific in most cases.

We also provide evidence suggesting that non–EMU countries have been net receivers of business cycles shocks from the core, the peripheral Eurozone and the new–EA countries, for the most part of the sample period. It should be noted however, that between the years 2011 and 2012, non–EMU countries appear to have contributed to the transmission of business cycle shocks to core Eurozone countries.

Additional evidence further implies shocks originating from the Eurozone periphery trigger considerable responses in all European groups. Finally, the cumulative response effects are more sizeable to cross-group business cycle shocks compared to shocks originating from own-group business cycles.

Summarising the results of the spillover effects among the world and the EU15, we find that the US is the dominant transmitter of shocks during the Great Recession. However, China is also showing a very important transmitting role of spillover effects, immediately after the Great Recession , as well as, during the fist years of the European debt crisis.

Overall, this study provides new insights on the transmission mechanism and the feedback effects of business cycle shocks in Europe. Prominent among our results is the fact that the core Eurozone countries are receiving business cycle spillover effects from almost all country groups. Furthermore, peripheral countries such as Spain (mainly) and Portugal and Greece (to a lesser extent), as well as, Czech Republic, Hungary and Poland exhibit a rather net–transmitting character when it comes to business cycles shocks in the years that followed the onset of the Great Recession. In this regard, shocks originating from the business cycles of peripheral Eurozone countries and new–EA countries are very important for the EU28 and, especially, for the Eurozone core.

These finding stress the importance of adopting – at both the national and the international level – the appropriate policy measures; that is, measures aiming to steer the peripheral and new–EA economies on an even keel, away from turbulence and close to recovery.

As our analysis has focused solely on the business cycles transmission mechanism, a straightforward avenue of future research, could be to extend the analysis by incorporating additional channels, such as the financial sector, trade and the uncertainty channel.

Acknowledgements

The authors like to thank the editor (Prof. Keith Blackburn), two anonymous reviewers and the participants of the 18th International Conference on Macroeconomic Analysis and International Finance, the 21st Annual Conference of the Multinational Finance Society, and the staff seminar at Vienna University of Economics and Business, for their valuable comments and suggestions on a previous version of this article. The usual disclaimer applies.

References

Altavilla, C., 2004. Do EMU members share the same business cycle? *Journal of Common Market Studies* 42 (5), 869–896.

Angeloni, I., Dedola, L., May 1999. *From the ERM to the euro: new evidence on economic and policy convergence among EU countries*. Working Paper Series 0004, European Central Bank.

Antonakakis, N., 2012a. Business cycle synchronization during us recessions since the beginning of the 1870s. *Economics Letters* 117 (2), 467–472.

Antonakakis, N., 2012b. Exchange return co-movements and volatility spillovers before and after the introduction of euro. *Journal of International Financial Markets, Institutions and Money* 22 (5), 1091–1109.

Antonakakis, N., Badinger, H., 2014. International business cycle spillovers since the 1870s. *Applied Economics* 46 (30), 3682–3694.
URL http://www.tandfonline.com/doi/abs/10.1080/00036846.2014.937040

Antonakakis, N., Vergos, K., 2013. Sovereign bond yield spillovers in the Euro zone during the financial and debt crisis. *Journal of International Financial Markets, Institutions and Money* 26, 258–272.

Arezki, R., Candelon, B., Sy, A., 2011. *Sovereign rating news and financial markets spillovers: Evidence from the European debt crisis*. IMF working papers (11/68), 1–27.

Artis, M., Chouliarakis, G., Harischandra, P. K. G., 2011. Business cycle synchronization since 1880. *Manchester School* 79 (2), 173–207.

Backus, D. K., Kehoe, P. J., Kydland, F. E., 1993. International business cycles: Theory vs. evidence. *Quarterly Review* 17 (4), 14–29.

Baxter, M., King, R. G., 1999. Measuring business cycles: Approximate band-pass filters for economic time series. *The Review of Economics and Statistics* 81 (4), 575–593.

Belo, F., 2001. *Some facts about the cyclical convergence in the Euro zone*. Working Papers w200107, Banco de Portugal, Economics and Research Department.

Bubák, V., Kočenda, E., Žikeš, F., 2011. Volatility transmission in emerging european foreign exchange markets. *Journal of Banking & Finance* 35 (11), 2829–2841.

Burns, A. F., Mitchell, W. C., September 1946. *Measuring business cycles*. NBER Books. National Bureau of Economic Research, Inc.

Calderŏn, C., Chong, A., Stein, E., 2007. Trade intensity and business cycle synchronization: Are developing countries any different? *Journal of International Economics* 71 (1), 2–21.

Canova, F., Ciccarelli, M., Ortega, E., 2012. Do institutional changes affect business cycles? Evidence from Europe. *Journal of Economic Dynamics and Control* 36 (10), 1520–1533.

Canova, F., Dellas, H., 1993. Trade interdependence and the international business cycle. *Journal of International Economics* 34 (1–2), 23–47.

Canova, F., Marrinan, J., 1998. Sources and propagation of international output cycles: Common shocks or transmission? *Journal of International Economics* 46 (1), 133–166.

Caporale, G. M., Rault, C., Sova, R., Sova, A., 2012. European free trade agreements and trade balance: Evidence from four new European Union members. *The Journal of International Trade & Economic Development* 21 (6), 839–863.

Caporale, G. M., Spagnolo, N., 2011. Stock market integration between three CEECs, Russia, and the UK. *Review of International Economics* 19 (1), 158–169.

Carstensen, K., Toubal, F., 2004. Foreign direct investment in Central and Eastern European countries: a dynamic panel analysis. *Journal of Comparative Economics* 32 (1), 3–22.

Claessens, S., Kose, M. A., Terrones, M. E., 2012. How do business and financial cycles interact? *Journal of International economics* 87 (1), 178–190.

Clark, T. E., van Wincoop, E., 2001. Borders and business cycles. *Journal of International Economics* 55 (1), 59–85.

Crespo-Cuaresma, J., Fernández-Amador, O., 2013a. Business cycle convergence in EMU: A first look at the second moment. *Journal of Macroeconomics* 37 (C), 265–284.

Crespo-Cuaresma, J., Fernández-Amador, O., 2013b. Business cycle convergence in EMU: A second look at the second moment. *Journal of International Money and Finance* 37 (C), 239–259.

Darvas, Z., Szapáry, G., 2008. Business cycle synchronization in the enlarged EU. *Open Economies Review* 19 (1), 1–19.

Davis, J. S., Huang, K. X. D., 2011. International real business cycles with endogenous markup variability. *Journal of International Economics* 85 (2), 302–316.

De Pace, P., 2013. Currency union, free-trade areas, and business cycle synchronization. *Macroeconomic Dynamics* 17, 646–680.

Degiannakis, S., Duffy, D., Filis, G., 2014. Business cycle synchronization in EU: A time-varying approach. *Scottish Journal of Political Economy.* 61 (348-370), 4.
URL http://onlinelibrary.wiley.com/doi/10.1111/sjpe.12049/abstract

Diebold, F. X., Yilmaz, K., 2009. Measuring financial asset return and volatility spillovers, with application to global equity markets. *Economic Journal* 119 (534), 158–171.

Diebold, F. X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting* 28 (1), 57–66.
URL http://www.sciencedirect.com/science/article/pii/S016920701100032X

Economist, February 19 2009. The collapse of manufacturing.
URL http://www.economist.com/node/13144864

Eickmeier, S., 2007. Business cycle transmission from the US to Germany – A structural factor approach. *European Economic Review* 51 (3), 521–551.

Fatas, A., 1997. EMU: Countries or regions? Lessons from the EMS experience. *European Economic Review* 41 (3-5), 743–751.

Fidrmuc, J., Korhonen, I., 2006. Meta-analysis of the business cycle correlation between the Euro area and the CEECs. *Journal of Comparative Economics* 34 (3), 518–537.

Gächter, M., Riedl, A., Ritzberger-Grünwald, D., 2012. Business cycle synchronization in the Euro area and the impact of the financial crisis. *Monetary Policy & the Economy* (2), 33–60.

Gayer, C., 2007. *A fresh look at business cycle synchronisation in the Euro area.* Directorate General Economic and Monetary Affairs 287, European Commission.

Gertler, M., Gali, J., Clarida, R. D., 1999. The science of monetary policy: A new keynesian perspective. *Journal of Economic Literature* 37 (4), 1661–1707.

Gomez, D. M., Ortega, G. J., Torgler, B., 2012. *Synchronization and diversity in business cycles: A network approach applied to the European Union.* CREMA Working Paper Series 2012-01, Center for Research in Economics, Management and the Arts (CREMA).

Gouveia, S., Correia, L., 2008. Business cycle synchronisation in the Euro area: the case of small countries. *International Economics and Economic Policy* 5 (1–2), 103–121.

Gregory, A. W., Smith, G. W., 1996. Measuring business cycles with business-cycle models. *Journal of Economic Dynamics and Control* 20 (6-7), 1007–1025.

Hughes Hallett, A., Richter, C., 2008. Have the Eurozone economies converged on a common European cycle? *International Economics and Economic Policy* 5 (1–2), 71–101.

Imbs, J., 2004. Trade, finance, specialization, and synchronization. *The Review of Economics and Statistics* 86 (3), 723–734.

Imbs, J., 2010. The first global recession in decades. *IMF Economic Review* 58 (2), 327–354.

Inklaar, R., Jong-A-Pin, R., de Haan, J., 2008. Trade and business cycle synchronization in OECD countries–A re-examination. *European Economic Review* 52 (4), 646–666.

Kalemli-Ozcan, S., Papaioannou, E., Peydró, J.-L., 2013. Financial Regulation, Financial Globalization, and the Synchronization of Economic Activity. *Journal of Finance* 68 (3), 1179–1228.

Kilian, L., 2009. Not all Oil Price Shocks are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *The American Economic Review* 99 (3), 1053–1069.

Koop, G., Pesaran, M. H., Potter, S. M., 1996. Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics* 74 (1), 119–147.

Kose, M. A., Otrok, C., Whiteman, C. H., 2003. International business cycles: World, region, and country-specific factors. *American Economic Review* 93 (4), 1216–1239.

Kose, M. A., Yi, K.-M., 2006. Can the standard international business cycle model explain the relation between trade and comovement? *Journal of international Economics* 68 (2), 267–295.

Kuznets, S., 1958. Long swings in the growth and population and in related economic variables. *Proceedings of the American Philsophical Society* 102, 25–52.

Lee, J., 2012. Measuring business cycle comovements in Europe: Evidence from a dynamic factor model with time-varying parameters. *Economics Letters* 115 (3), 438–440.

Lee, J., 2013. Business cycle synchronization in Europe: Evidence from a dynamic factor model. *International Economic Journal* 27 (3), 347–364.

Lehwald, S., 2012. Has the Euro changed business cycle synchronization? Evidence from the core and the periphery. *Empirica*, 1–30.

Lumsdaine, R. L., Prasad, E. S., 2003. Identifying the common component of international economic fluctuations: A new approach. *Economic Journal* 113 (484), 101–127.

Marin, D., 2006. A new international division of labor in Europe: Outsourcing and offshoring to Eastern Europe. *Journal of the European Economic Association* 4 (2-3), 612–622.

Marin, D., Verdier, T., 2014. Corporate hierarchies and international trade: Theory and evidence. *Journal of International Economics* 94 (2), 295–310.

McKinnon, R. I., 1963. Optimum currency areas. *The American Economic Review* 53, 717–725.

McMillan, D. G., Speight, A. E., 2010. Return and volatility spillovers in three euro exchange rates. *Journal of Economics and Business* 62 (2), 79–93.

Michaelides, P. G., Papageorgiou, T., Vouldis, A. T., 2013. Business cycles and economic crisis in Greece (1960-2011): A long run equilibrium analysis in the Eurozone. *Economic Modelling* 31 (C), 804–816.

Mitchell, W. C., 1927. *Business cycles: The problem and its setting*. NBER Books. National Bureau of Economic Research, Inc.

Mundell, R. A., 1961. A theory of optimum currency areas. *The American Economic Review* 51, 657–665.

Ng, E. C., 2010. Production fragmentation and business-cycle comovement. *Journal of International Economics* 82 (1), 1–14.

Papageorgiou, T., Michaelides, P. G., Milios, J. G., 2010. Business cycles synchronization and clustering in Europe (1960–2009). *Journal of Economics and Business* 62 (5), 419–470.

Pesaran, H. H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. *Economics Letters* 58 (1), 17–29.

Rogoff, K., 1985. The optimal degree of commitment to an intermediate monetary target. *The Quarterly Journal of Economics* 100 (4), 1169–1189.

Savva, C. S., Neanidis, K. C., Osborn, D. R., 2010. Business cycle synchronization of the Euro area with the new and negotiating member countries. *International Journal of Finance & Economics* 15 (3), 288–306.

Sims, C., 1980. Macroeconomics and reality. *Econometrica* 48, 1–48.

Weyerstrass, K., van Aarle, B., Kappler, M., Seymen, A., 2011. Business cycle synchronisation with(in) the Euro area: in search of a Euro effect. *Open Economies Review* 22 (3), 427–446.

Yetman, J., 2011. Exporting recessions: International links and the business cycle. *Economics Letters* 110 (1), 12–14.

Yilmaz, K., 2009. *International Business Cycle Spillovers*. Koc University-TUSIAD Economic Research Forum Working Papers 0903, Koc University-TUSIAD Economic Research Forum.

Yilmaz, K., 2010. Return and volatility spillovers among the East Asian equity markets. *Journal of Asian Economics* 21 (3), 304–313.

Zhou, X., Zhang, W., Zhang, J., 2012. Volatility spillovers between the Chinese and world equity markets. *Pacific-Basin Finance Journal* 20 (2), 247–270.

Table 1: Descriptive statistics of EU15 member countries' business cycles (1977M1–2014M2)

	obs	min	mean	max	Std. Dev.	Skewness	Excess Kurtosis	Jarque-Bera	ADF
AUT	462	-0.2280	0.0305	0.2000	0.0501	-1.5253***	2.8185***	113.57***	-5.445***
BEL	462	-0.1473	0.0206	0.1449	0.0482	-0.94961***	1.0550***	31.074***	-2.923**
BLG	162	-0.2699	0.0315	0.1733	0.0858	-1.4189***	2.2618***	86.698***	-3.307**
HRV	271	-0.3696	0.0027	0.2078	0.0804	-0.45378**	-0.2033	5.6947*	-5.826***
CYP	306	-0.3042	-0.0024	0.2825	0.0678	-0.39641**	-0.0872	4.1881	-4.938***
CZE	247	-0.2392	0.0268	0.1595	0.0676	-1.5152***	2.6826***	107.84***	-2.962**
DNK	462	-0.2282	0.0204	0.2591	0.0753	-1.0955***	1.6746***	50.062***	-7.134***
EST	182	-0.3994	0.0546	0.3151	0.1225	-1.3898***	3.0149***	110.70***	-3.871***
FIN	463	-0.2642	0.0254	0.2107	0.0652	-1.4336***	2.9536***	111.55***	-3.034**
FRA	462	-0.2276	0.00676	0.1419	0.0411	-2.1033***	5.2081***	295.07***	-3.231**
GER	460	-0.2764	0.0171	0.1597	0.0554	-1.6538***	3.6733***	160.85***	-3.415**
GRC	463	-0.2352	0.0004	0.2478	0.0582	-0.64076***	0.1969	11.067**	-7.641***
HUN	403	-0.3201	0.0268	0.2392	0.0898	-1.8437***	3.7138***	180.31***	-2.921**
IRL	448	-0.1850	0.0632	0.3298	0.0764	0.30599	0.8484**	7.2043**	-9.973***
ITA	460	-0.2951	0.00808	0.1642	0.0591	-1.8717***	4.5060***	225.92***	-3.328**
LVA	175	-0.2840	0.0444	0.3618	0.0974	-0.66303***	2.3436***	47.734***	-3.161**
LTU	199	-0.2540	0.0469	0.3192	0.1159	-0.32764*	0.2391	3.2032	-6.538***
LUX	462	-0.3145	0.0163	0.2439	0.0789	-1.3564***	2.6880***	96.018***	-3.561***
MLT	158	-0.2496	-0.0044	0.1670	0.0839	-0.42657**	-0.1437	4.9275	-4.259***
NED	462	-0.2106	0.0142	0.1265	0.0424	-0.69670***	2.5072***	54.166***	-4.819***
POL	341	-0.3937	0.0340	0.2140	0.0979	-0.56848***	0.4108	9.6215***	-3.671***
PRT	463	-0.1631	0.0196	0.2184	0.0561	-0.33046*	0.4430	4.1679	-6.397***
ROM	270	-0.4581	0.0170	0.1683	0.1073	-1.1118***	2.2478***	65.810***	-4.583***
SVK	293	-0.5517	0.0328	0.4082	0.1201	-1.3442***	2.6129***	92.529***	-3.096**
SVN	258	-0.2797	0.0151	0.1293	0.0679	-2.1757***	5.0747***	294.19***	-2.939**
ESP	460	-0.2663	0.0073	0.1274	0.0523	-1.9913***	4.0067***	210.10***	-2.978**
SWE	456	-0.2883	0.0091	0.4508	0.0708	-1.4955***	2.9958***	117.98***	-2.954**
UK	463	-0.1286	0.0066	0.0921	0.0380	-1.5602***	3.0997***	127.35***	-2.956**
US	464	-0.1628	0.0239	0.1149	0.0429	-1.8743***	3.3887***	168.11***	-3.193**
CHN	285	-0.2111	0.0023	0.4481	0.0587	1.5591***	11.727***	1748.5***	-11.89***

Note: ADF denotes Augmented Dickey Fuller tests with 10%, 5% and 1% critical values of -2.5704, -2.8682 and -3.4457, respectively. *, ** and *** indicate significance at 10%, 5% and 1% level, respectively.

Table 2: Spillover table of business cycle shocks in EU15 (1977M1–2014M2)

	From (j)															
To (i)	AUT	BEL	DNK	FIN	FRA	GER	GRC	IRL	ITA	LUX	NED	PRT	ESP	SWE	UK	From Others
AUT	24.27	1.13	0.09	1.77	7.27	12.32	1.82	0.70	2.77	8.59	3.79	0.25	19.12	7.24	8.86	75.73
BEL	0.92	34.03	0.33	1.62	6.49	10.00	0.29	1.42	4.26	7.25	1.99	0.61	14.86	1.28	14.64	65.97
DNK	0.34	0.51	56.68	1.88	5.36	2.55	1.06	0.39	2.01	6.57	1.23	2.15	9.84	3.67	5.77	43.32
FIN	0.97	0.54	0.86	41.09	4.05	1.96	2.82	1.55	5.81	6.31	3.83	0.73	16.63	5.29	7.57	58.91
FRA	0.60	1.49	0.47	1.33	20.66	8.81	0.92	0.67	7.42	8.89	3.40	0.82	25.37	5.41	13.75	79.34
GER	0.57	2.13	0.11	0.36	9.90	28.43	0.30	0.23	4.57	9.60	3.93	1.22	20.89	5.31	12.45	71.57
GRC	0.61	0.85	1.35	1.58	1.61	1.23	73.63	0.41	0.75	3.00	1.17	0.25	9.87	1.13	2.55	26.37
IRL	0.61	2.02	0.82	1.55	2.58	0.74	0.61	65.84	1.68	2.79	1.58	0.64	13.41	2.50	2.64	34.16
ITA	0.61	1.26	0.41	2.06	12.36	5.16	0.90	0.61	26.26	9.67	1.99	1.42	23.60	4.38	9.30	73.74
LUX	1.35	1.83	0.30	0.58	5.35	6.10	0.17	1.55	4.11	49.50	1.48	1.60	15.20	2.19	8.69	50.50
NED	1.02	0.70	0.56	0.36	6.85	6.82	0.46	1.10	3.77	6.86	48.77	0.28	10.45	3.69	8.33	51.23
PRT	0.64	0.49	1.46	0.58	5.87	1.75	0.20	1.80	5.11	3.22	0.52	63.59	12.42	0.14	2.21	36.41
ESP	0.56	0.44	0.51	2.05	5.27	4.81	0.71	1.10	4.60	6.46	0.44	1.01	57.38	4.82	9.84	42.62
SWE	0.29	0.30	0.07	3.95	5.03	9.85	1.97	0.39	2.82	8.01	3.42	0.10	10.25	43.66	9.88	56.34
UK	1.88	2.43	2.18	1.56	5.51	4.70	0.13	2.17	5.89	3.56	2.32	0.30	9.48	1.03	56.86	43.14
Contr. to others	10.97	16.12	9.50	21.23	83.52	76.79	12.38	14.10	55.54	90.78	31.09	11.40	211.40	48.07	116.46	Total Spillover
Contr. incl. own	35.23	50.15	66.19	62.32	104.17	105.22	86.01	79.93	81.81	140.27	79.85	74.99	268.78	91.74	173.33	Index = 53.96%
Net spillovers	-64.77	-49.85	-33.81	-37.68	4.17	5.22	-13.99	-20.07	-18.19	40.27	-20.15	-25.01	168.78	-7.26	73.33	

Note: Spillover indices, given by Equations (2)–(7), calculated from variance decompositions based on 24–step-ahead forecasts.

Table 3: Generalised cumulative impulse responses, EU15 (1977M1–2014M2)

		From (j)					
		Within–country			*Between–country*		
	To(i)	Core	Periphery	Non-EMU	Core	Periphery	Non-EMU
12-months	Core	3.434			5.416	10.623	4.719
	Periphery		3.979		5.955	5.585	7.008
	Non-EMU			3.466	0.013	6.549	13.913
24-months	Core	3.710			6.432	16.759	7.854
	Periphery		4.776		6.776	7.240	11.705
	Non-EMU			4.117	1.032	6.606	15.185
36-months	Core	3.666			6.469	19.456	9.091
	Periphery		5.013		6.555	7.702	13.215
	Non-EMU			4.283	1.307	5.799	15.121
48-months	Core	3.663			6.464	20.495	9.539
	Periphery		5.097		6.458	7.837	13.678
	Non-EMU			4.335	1.370	5.346	15.348

Notes: Cumulative generalized impulse response to one standard deviation shock, multiplied by 100 (in %). All entries are averages over country-specific shocks to the respective business cycle.

Table 4: Spillover table of business cycle shocks in EU28 (2000M1–2014M2)

	From (j)																												
To (i)	AUT	BEL	BLG	HRV	CYP	CZE	DNK	EST	FIN	FRA	GER	GRC	HUN	IRL	ITA	LVA	LTU	LUX	MLT	NED	POL	PRT	ROM	SVK	SVN	ESP	SWE	UK	From Others
AUT	13.44	1.93	0.77	0.30	2.19	3.14	0.48	8.51	1.71	8.30	4.52	1.17	1.55	0.99	8.32	3.80	0.69	2.91	3.67	1.68	4.72	3.57	0.82	2.33	1.49	10.38	4.29	2.34	86.56
BEL	1.14	8.92	0.57	0.28	3.63	5.03	0.45	4.83	0.67	7.39	4.11	0.53	2.25	1.29	11.36	1.48	0.98	2.22	1.89	1.62	5.71	6.27	3.45	2.55	1.34	14.40	1.21	4.41	91.08
BLG	1.28	0.74	11.93	1.72	2.16	3.99	0.96	5.58	0.53	4.80	1.68	2.23	3.49	1.44	7.60	3.01	1.97	4.35	1.45	0.41	2.00	5.48	0.62	2.52	1.61	20.81	1.59	4.05	88.07
HRV	0.94	1.03	5.24	23.69	3.99	2.32	4.10	2.50	1.96	1.46	0.37	0.95	1.60	1.93	2.89	4.00	0.88	5.14	0.32	0.42	2.04	5.98	1.10	0.99	4.57	15.62	0.72	3.27	76.31
CYP	1.69	2.81	4.98	4.54	39.47	0.83	3.22	0.71	2.12	1.23	4.48	0.66	0.72	1.12	1.09	3.47	2.47	5.36	0.38	0.45	0.74	2.62	2.00	2.52	1.78	6.00	2.05	0.50	60.53
CZE	1.65	1.66	0.34	0.34	2.44	11.36	0.42	5.47	0.61	7.10	4.04	0.75	3.41	2.19	9.84	3.12	1.03	2.99	1.55	0.29	4.60	6.72	2.96	2.25	1.60	17.38	0.60	3.29	88.64
DNK	1.65	1.40	1.61	3.12	2.70	3.72	18.48	5.70	1.18	7.36	2.68	0.71	2.10	0.86	6.35	2.99	1.35	2.14	1.57	1.44	2.43	5.36	0.82	2.16	2.08	10.95	1.38	5.71	81.52
EST	1.26	2.33	0.44	0.23	1.63	3.68	0.19	13.11	0.50	9.11	4.36	0.90	2.18	1.12	11.58	2.98	1.23	3.09	1.79	0.67	3.56	6.17	1.11	2.73	1.24	16.61	2.52	3.67	86.89
FIN	1.68	1.07	0.29	0.28	1.46	3.75	0.16	6.91	10.19	8.21	3.30	1.78	2.18	1.17	9.12	3.44	0.82	3.05	2.38	2.53	4.34	4.78	1.59	2.66	2.27	15.49	1.82	3.28	89.81
FRA	1.35	2.46	0.41	0.15	3.04	4.24	0.19	6.41	0.44	13.15	5.60	0.82	2.23	1.24	10.42	2.82	1.18	2.12	1.66	1.95	5.14	5.43	2.16	2.90	1.49	15.16	0.98	4.84	86.85
GER	1.26	2.28	0.66	0.08	3.64	3.83	0.09	6.54	0.41	10.62	10.36	0.93	2.18	0.85	12.05	1.56	0.75	1.56	2.26	1.21	5.68	5.27	2.52	3.34	1.56	13.62	0.92	3.95	89.64
GRC	1.88	2.47	4.45	1.64	1.39	1.21	1.55	2.65	2.43	1.84	1.47	39.79	1.32	0.89	1.74	2.93	1.57	2.50	2.46	0.71	0.55	2.46	0.69	0.70	2.68	13.16	1.44	1.43	60.21
HUN	1.42	1.20	0.23	0.33	1.94	3.99	0.18	6.08	0.58	8.61	4.22	0.71	7.95	1.59	10.47	3.35	0.87	3.27	1.59	0.82	3.99	6.01	1.77	2.96	2.07	18.38	1.12	4.31	92.05
IRL	1.72	0.51	1.54	1.45	1.20	1.29	0.43	2.54	1.01	3.64	0.53	2.40	2.90	52.61	2.74	2.84	1.09	2.64	0.93	1.35	1.23	5.07	1.90	0.97	0.41	3.92	0.43	0.71	47.39
ITA	1.18	1.99	0.34	0.39	2.17	3.76	0.03	6.20	0.43	8.64	5.37	0.70	2.67	1.16	14.51	2.07	0.96	2.91	1.91	1.24	4.77	6.76	2.33	3.39	1.67	17.48	1.28	3.67	85.49
LVA	1.60	2.38	0.85	0.22	1.71	3.60	0.29	9.42	0.34	7.07	1.49	1.68	1.82	3.21	6.84	21.27	1.13	5.27	1.19	1.30	2.18	5.82	1.02	2.25	1.64	11.84	1.42	1.14	78.73
LTU	1.07	1.25	2.16	0.13	2.94	1.87	0.09	5.06	0.62	6.45	1.98	1.89	1.55	1.71	4.60	4.93	35.14	2.34	1.04	1.04	1.78	3.32	0.85	1.60	1.22	7.95	1.54	3.90	64.86
LUX	1.64	1.08	0.29	0.71	1.06	4.01	0.14	3.73	1.52	4.70	2.00	0.64	2.55	1.69	7.52	2.63	1.41	20.16	1.51	2.39	2.77	6.34	1.26	3.20	2.32	17.33	2.74	2.67	79.84
MLT	2.10	0.56	0.19	0.10	0.55	2.56	0.30	3.67	2.58	4.09	5.13	2.81	1.13	0.26	8.80	1.10	1.13	3.93	24.23	1.97	4.03	2.58	0.41	11.20	1.16	9.72	2.39	1.34	75.77
NED	0.86	1.51	0.68	0.24	2.12	1.98	0.17	3.88	1.24	11.06	2.74	0.65	1.03	1.09	5.90	2.30	2.07	2.40	2.16	31.60	4.31	2.26	0.95	1.86	2.10	7.03	0.63	5.20	68.40
POL	2.18	1.35	0.30	1.17	1.91	4.66	0.37	4.98	1.46	5.33	5.11	0.96	4.18	1.84	10.20	1.89	1.23	2.07	1.22	0.36	21.58	5.53	1.37	2.96	1.74	11.64	0.65	1.77	78.42
PRT	0.39	1.51	1.13	2.85	2.22	3.53	3.16	2.02	0.46	3.62	3.16	0.33	2.28	2.49	8.85	1.59	1.32	1.66	1.11	0.34	3.35	30.18	6.16	2.45	1.04	9.91	0.69	2.18	69.82
ROM	0.84	0.66	0.30	0.33	3.83	6.30	0.28	3.17	1.40	5.60	4.60	0.73	1.35	1.55	7.53	1.99	0.81	0.63	1.92	0.62	4.01	5.62	24.63	3.02	1.32	13.56	0.38	3.04	75.37
SVK	1.25	0.36	1.14	0.40	2.11	2.99	0.23	3.55	0.30	6.27	3.99	1.03	0.90	0.95	10.55	3.42	1.31	1.47	4.91	2.99	5.28	4.42	3.91	21.61	1.41	10.57	0.59	2.13	78.39
SVN	1.60	1.36	0.42	1.04	2.31	3.67	0.71	5.74	0.41	8.84	4.37	0.81	2.28	1.34	9.54	3.87	0.82	2.98	1.89	1.71	4.02	5.48	1.94	3.36	8.62	15.75	1.47	3.66	91.38
ESP	1.08	0.85	0.50	1.27	1.43	4.84	0.12	5.19	0.44	7.21	2.40	0.68	3.49	1.71	10.65	2.24	0.93	2.93	1.10	0.68	3.30	7.72	2.00	1.62	1.39	29.00	0.92	4.32	71.00
SWE	1.39	1.45	0.57	0.13	1.80	3.67	0.10	9.16	0.55	9.25	5.02	1.20	2.06	0.96	10.61	3.03	0.85	3.37	2.95	0.91	4.02	4.93	0.95	3.49	2.01	14.68	8.06	2.83	91.94
UK	1.97	1.86	0.26	0.75	2.50	4.10	0.73	4.32	0.45	8.26	4.15	0.80	3.05	1.20	10.23	1.62	1.06	1.81	1.68	1.11	4.97	5.84	1.47	3.78	1.64	16.79	0.80	12.80	87.20
Contr. to others	38.05	40.05	30.69	24.19	60.06	92.56	19.12	134.53	26.34	176.05	92.88	29.43	58.43	37.85	217.37	74.47	31.92	77.10	48.51	32.20	95.53	137.80	48.12	75.73	46.85	356.15	36.56	83.63	Total Spillover
Contri. incl. own	51.49	48.98	42.62	47.88	99.53	103.91	37.60	147.64	36.53	189.20	103.24	69.22	66.37	90.47	231.88	95.75	67.05	97.27	72.74	63.80	117.11	167.98	72.74	97.34	55.47	385.15	44.62	96.43	Index = 79.36%
Net spillovers	-48.51	-51.02	-57.38	-52.12	-0.47	3.91	-62.40	47.64	-63.47	89.20	3.24	-30.78	-33.63	-9.53	131.88	-4.25	-32.95	-2.73	-27.26	-36.20	17.11	67.98	-27.26	-2.66	-44.53	285.15	-55.38	-3.57	

Note: Spillover indices, given by Equations (2)–(7), calculated from variance decompositions based on 24–step-ahead forecasts.

Table 5: Generalised cumulative impulse responses, EU28 (2000M1–2014M2)

		From (j)							
		Within–country				*Between–country*			
	To(i)	Core	Periphery	Non-EMU	New-EA	Core	Periphery	Non-EMU	New-EA
12-months	Core	3.451				3.385	20.495	4.472	7.950
	Periphery		4.357			6.626	15.587	1.746	7.312
	Non-EMU			2.554		1.431	18.328	5.399	4.600
	New-EA				3.271	11.534	16.011	0.150	5.387
24-months	Core	4.230				4.274	22.644	5.893	9.293
	Periphery		6.124			7.132	16.208	2.482	8.011
	Non-EMU			2.586		1.534	20.636	6.974	5.889
	New-EA				3.923	12.074	19.611	0.299	7.979
36-months	Core	5.103				4.356	24.161	6.439	10.775
	Periphery		7.495			7.277	18.334	2.829	10.667
	Non-EMU			2.798		1.600	21.766	7.461	6.263
	New-EA				4.488	13.804	22.513	0.419	9.744
48-months	Core	6.946				4.843	28.190	6.542	11.630
	Periphery		9.873			8.085	20.657	3.193	11.990
	Non-EMU			3.374		1.983	22.978	7.616	6.371
	New-EA				5.452	14.169	23.098	0.439	10.193

Notes: Cumulative generalized impulse response to one standard deviation shock, multiplied by 100 (in %). All entries are averages over country-specific shocks to the respective business cycle.

Table 6: Spillover table of business cycle shocks in EU15, US and China (1977M1–2014M2)

	From (j)																	
To (i)	AUT	BEL	DNK	FIN	FRA	GER	GRC	IRL	ITA	LUX	NED	PRT	ESP	SWE	UK	US	CHN	From Others
AUT	27.12	1.25	0.74	2.84	7.65	6.75	1.36	0.90	2.83	4.52	1.69	0.56	17.45	6.16	3.00	13.63	1.55	72.88
BEL	1.47	27.32	2.24	1.38	7.66	6.54	0.52	0.39	4.42	5.56	1.15	4.72	20.55	1.51	2.77	10.82	0.98	72.68
DNK	1.54	1.76	50.97	2.12	3.76	1.25	0.29	0.68	2.48	3.99	0.57	1.39	13.64	2.90	1.90	10.03	0.75	49.03
FIN	3.25	2.36	0.77	25.44	3.58	1.37	1.80	0.14	3.14	4.10	1.40	0.08	14.17	6.05	8.43	21.82	2.10	74.56
FRA	1.84	1.57	0.92	1.08	17.47	6.05	0.32	0.56	6.52	6.33	2.11	1.44	26.05	3.76	5.18	16.95	1.84	82.53
GER	1.34	1.87	0.97	1.16	12.59	21.98	0.38	1.43	4.66	4.91	1.75	1.65	21.10	4.49	2.41	15.36	1.95	78.02
GRC	1.70	3.03	0.04	2.01	1.92	0.99	65.47	0.23	0.20	1.31	1.12	0.18	9.49	7.21	1.48	2.81	0.79	34.53
IRL	1.13	1.75	0.39	2.11	1.86	1.01	1.24	57.51	3.52	1.94	0.49	5.53	12.26	0.67	2.82	5.45	0.33	42.49
ITA	2.17	1.74	0.48	1.08	8.49	3.32	0.20	0.30	17.02	7.38	0.72	1.71	27.10	2.86	6.09	17.58	1.75	82.98
LUX	1.39	1.49	2.19	1.30	4.57	2.16	0.13	0.20	3.29	43.80	1.15	1.60	21.21	2.20	4.82	6.96	1.54	56.20
NED	1.23	1.17	1.32	0.75	11.04	1.98	0.20	0.62	3.83	3.06	44.68	0.65	10.80	1.66	6.95	8.02	2.03	55.32
PRT	0.63	3.12	0.83	0.28	4.44	2.43	0.28	4.69	7.22	2.00	0.67	48.66	18.73	0.95	1.42	2.91	0.74	51.34
ESP	1.68	1.61	0.22	1.30	8.00	1.80	1.38	0.18	5.21	5.46	0.16	2.12	48.27	3.42	4.20	14.10	0.88	51.73
SWE	1.39	0.94	0.61	2.83	5.33	6.21	4.20	1.38	1.38	4.09	0.94	0.58	9.57	37.09	7.09	13.69	2.67	62.91
UK	5.80	3.15	1.07	1.34	3.97	3.03	0.28	0.06	3.64	4.85	0.98	0.17	13.84	2.69	26.49	26.20	2.43	73.51
US	5.99	3.50	0.44	1.82	4.21	1.68	0.29	0.67	1.24	2.99	1.12	0.03	12.49	3.22	2.44	54.85	3.02	45.15
CHN	0.82	3.12	3.13	0.77	1.46	1.34	0.49	0.23	0.91	1.48	1.44	1.30	0.38	0.99	0.58	3.47	78.11	21.89
Contr. to others	33.36	33.44	16.37	24.18	90.54	47.92	13.34	12.69	54.51	63.98	17.47	23.70	248.82	50.76	61.57	189.81	25.33	Total Spillover
Contr. incl. own	60.48	60.76	67.33	49.61	108.01	69.90	78.81	70.20	71.53	107.78	62.15	72.35	297.09	87.84	88.06	244.65	103.44	Index = 59.28%
Net spillovers	-39.52	-39.24	-32.77	-50.49	8.01	-30.10	-21.19	-29.80	-28.47	7.78	-37.85	-27.65	197.09	-12.16	-11.94	144.65	3.44	

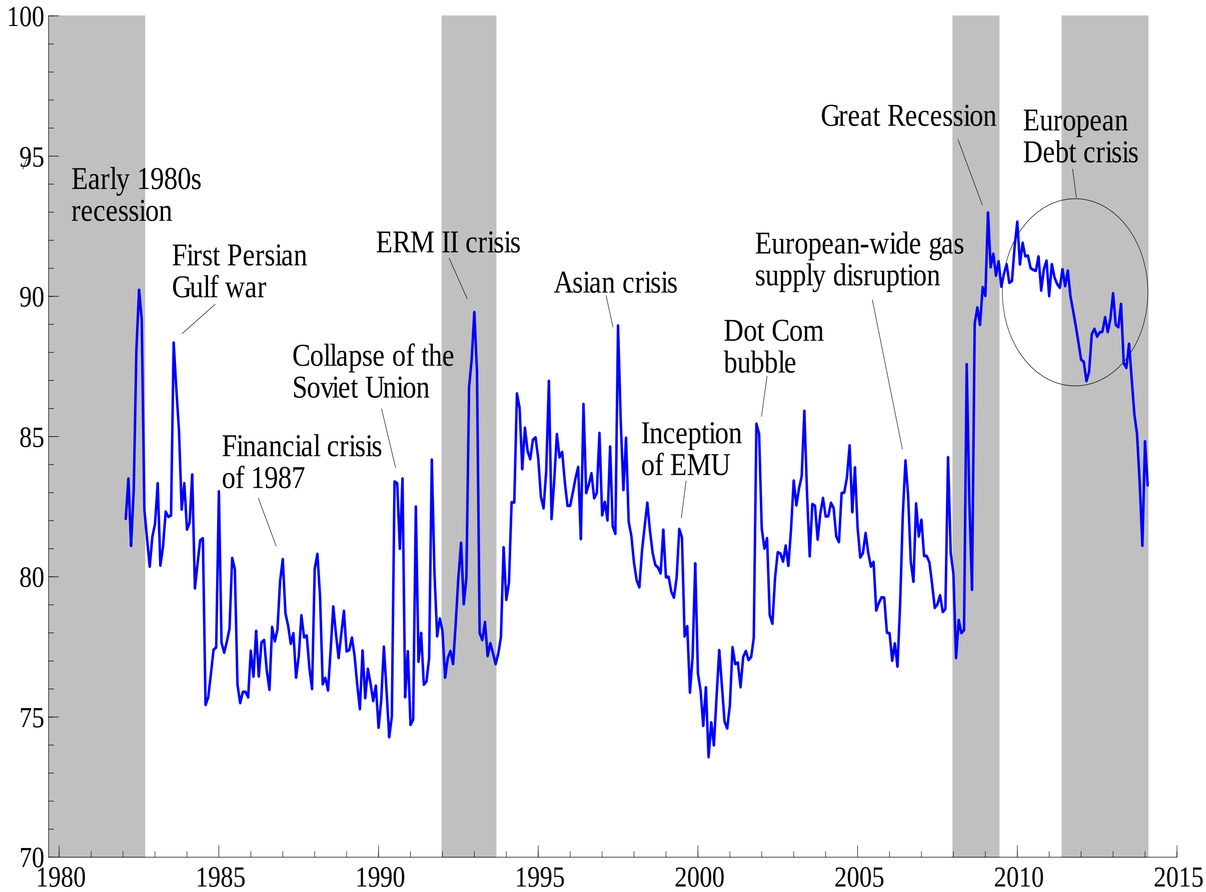
Note: Spillover indices, given by Equations (2)–(7), calculated from variance decompositions based on 24–step-ahead forecasts.

Table 7: Generalised cumulative impulse responses, EU15, US and China (1977M1–2014M2)

		From (j)							
		Within–country				*Between–country*			
	To(i)	Core	Periphery	Non-EMU	World	Core	Periphery	Non-EMU	World
12-months	Core	2.967				0.325	12.508	7.710	4.382
	Periphery		3.737			2.537	5.601	3.948	9.492
	Non-EMU			2.788		2.082	11.722	5.191	16.364
	World				6.117	1.112	1.340	1.279	9.006
24-months	Core	2.979				0.472	17.687	8.172	4.315
	Periphery		4.444			3.337	7.339	4.123	10.183
	Non-EMU			3.180		3.078	14.447	6.936	26.530
	World				9.646	2.742	2.457	1.745	13.642
36-months	Core	2.843				0.912	19.756	10.053	4.421
	Periphery		4.700			4.403	8.115	4.165	9.537
	Non-EMU			3.365		3.585	15.200	8.535	32.720
	World				11.811	3.802	3.501	1.999	16.385
48-months	Core	2.751				0.907	20.880	12.824	4.599
	Periphery		4.842			5.204	8.549	4.154	9.224
	Non-EMU			3.486		3.916	15.594	9.757	36.762
	World				13.215	4.465	4.250	2.173	18.224

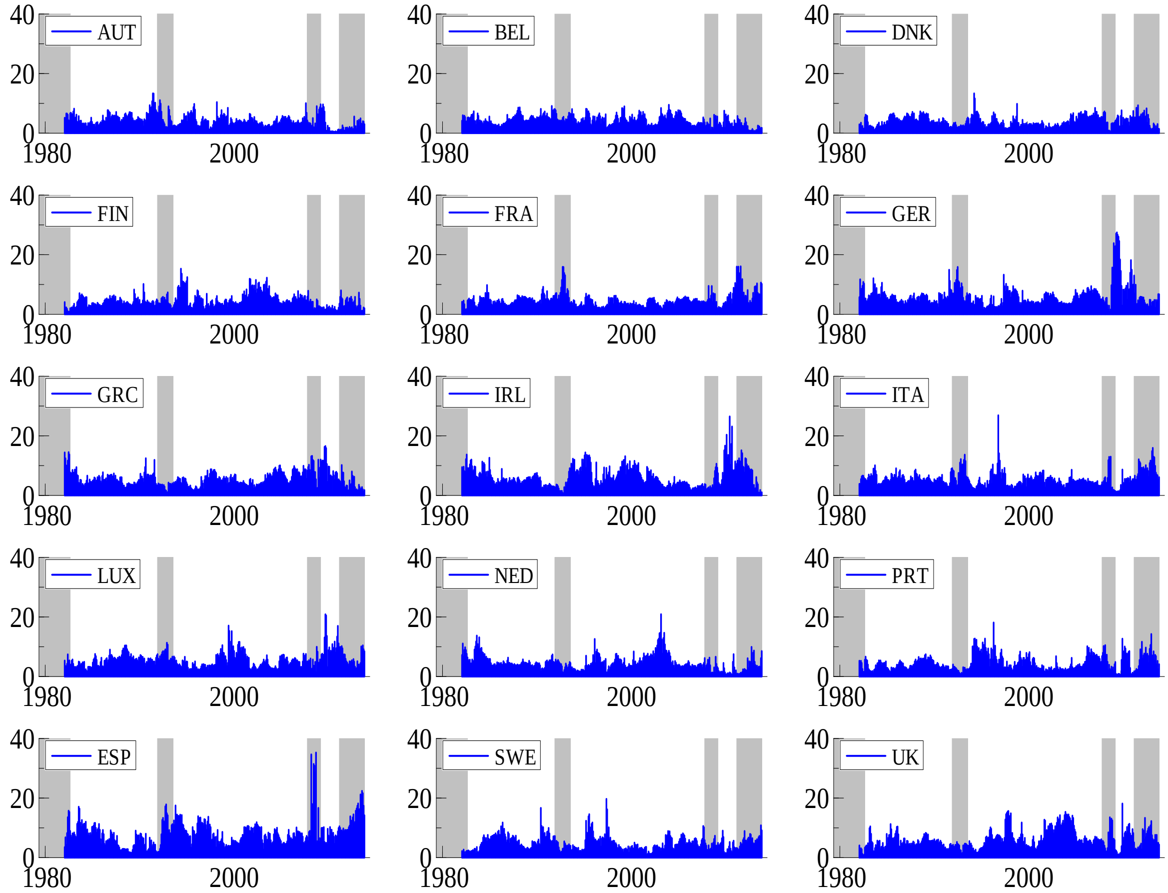
Notes: Cumulative generalized impulse response to one standard deviation shock, multiplied by 100 (in %). All entries are averages over country-specific shocks to the respective business cycle.

Figure 1: Total spillover of business cycles in the EU15



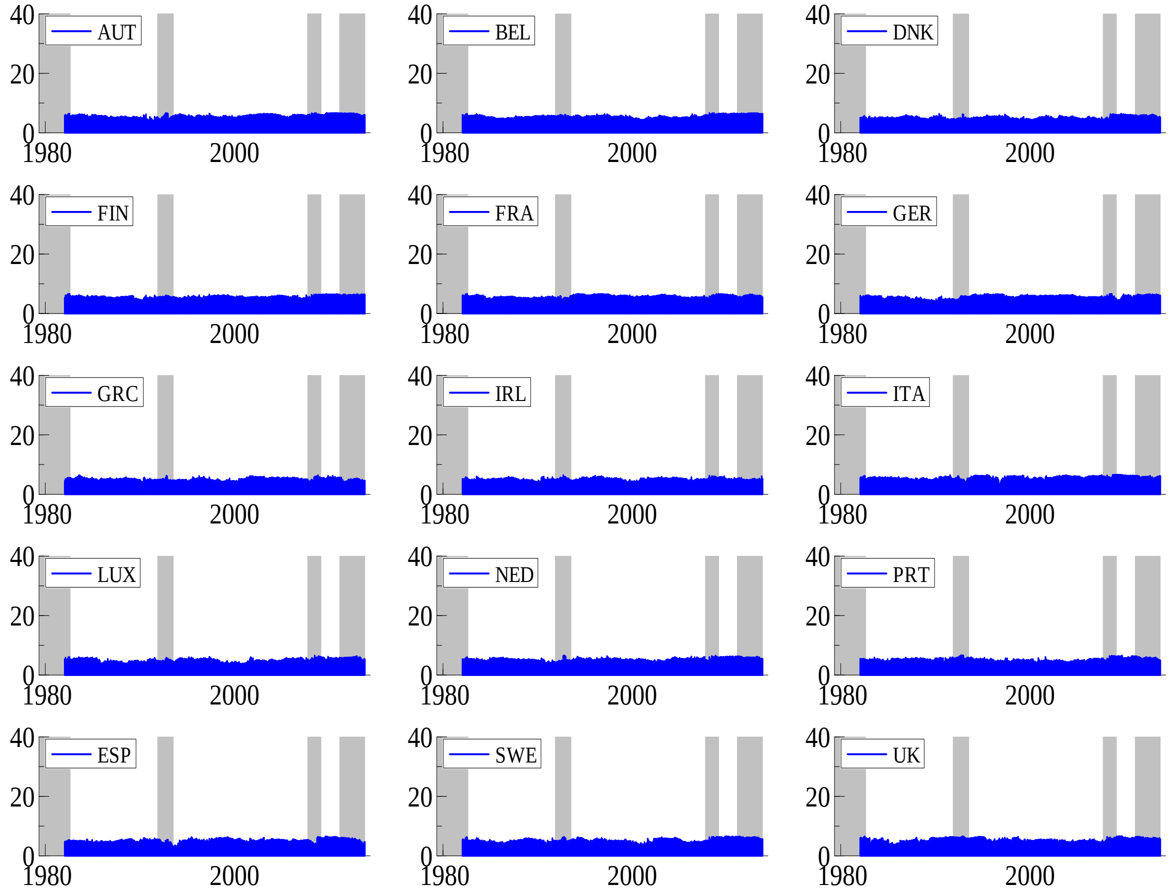
Note: Plot of moving total spillover index estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 2: Directional spillovers $FROM$ each of the EU15 business cycles to all others



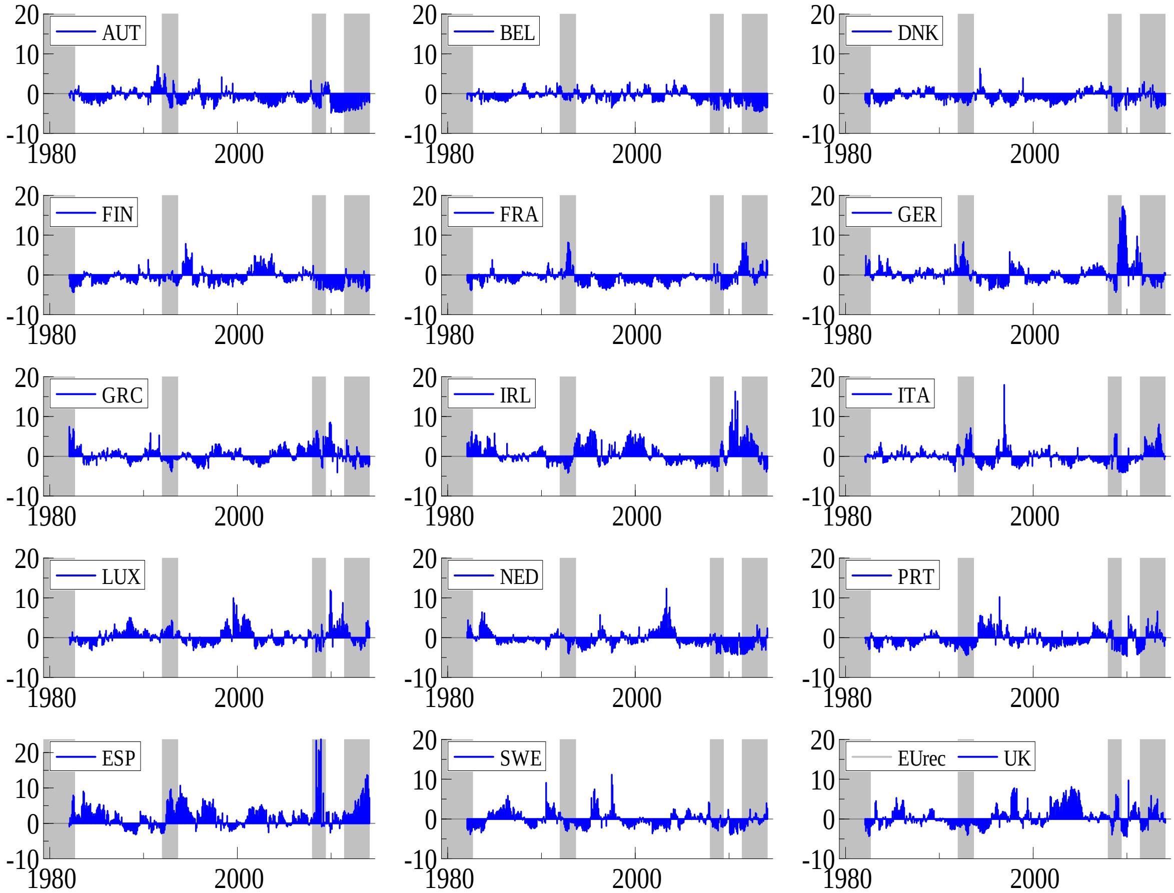
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 3: Directional spillovers *TO* each of the EU15 business cycles from all others



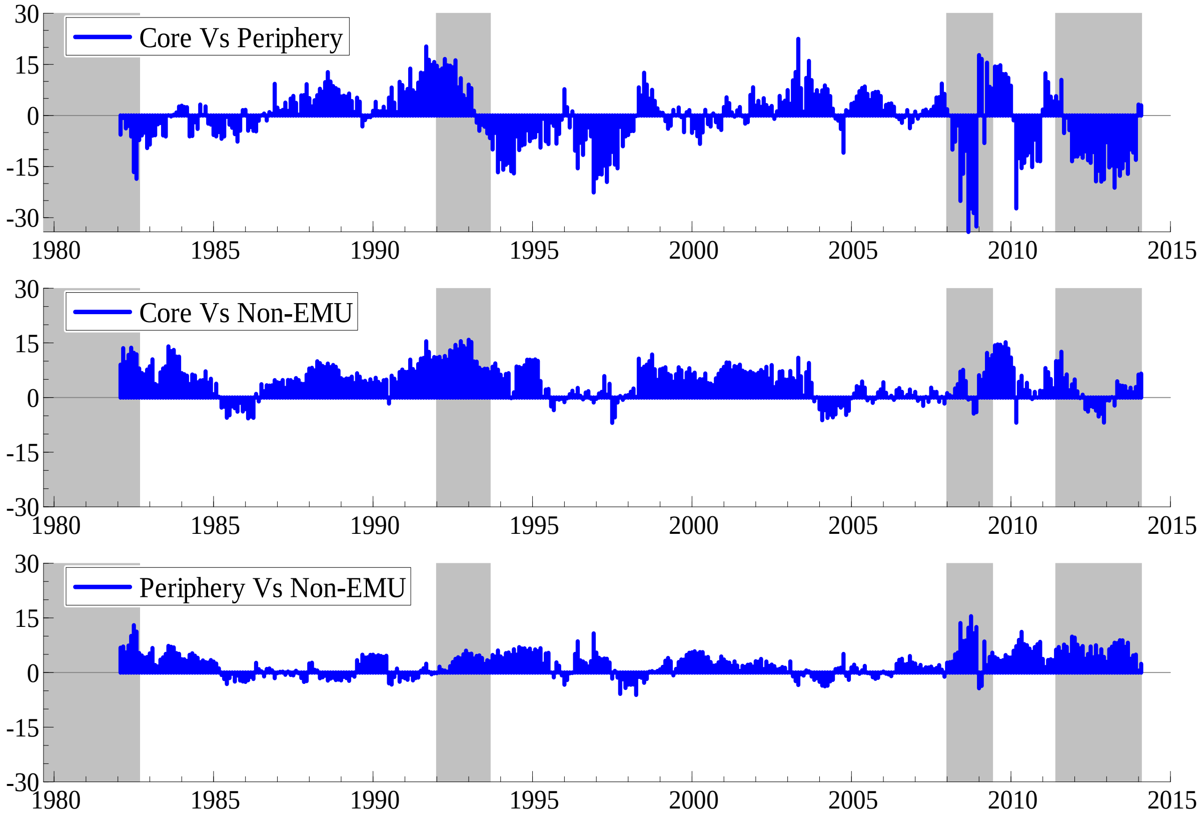
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 4: Net spillovers of business cycles in the EU15



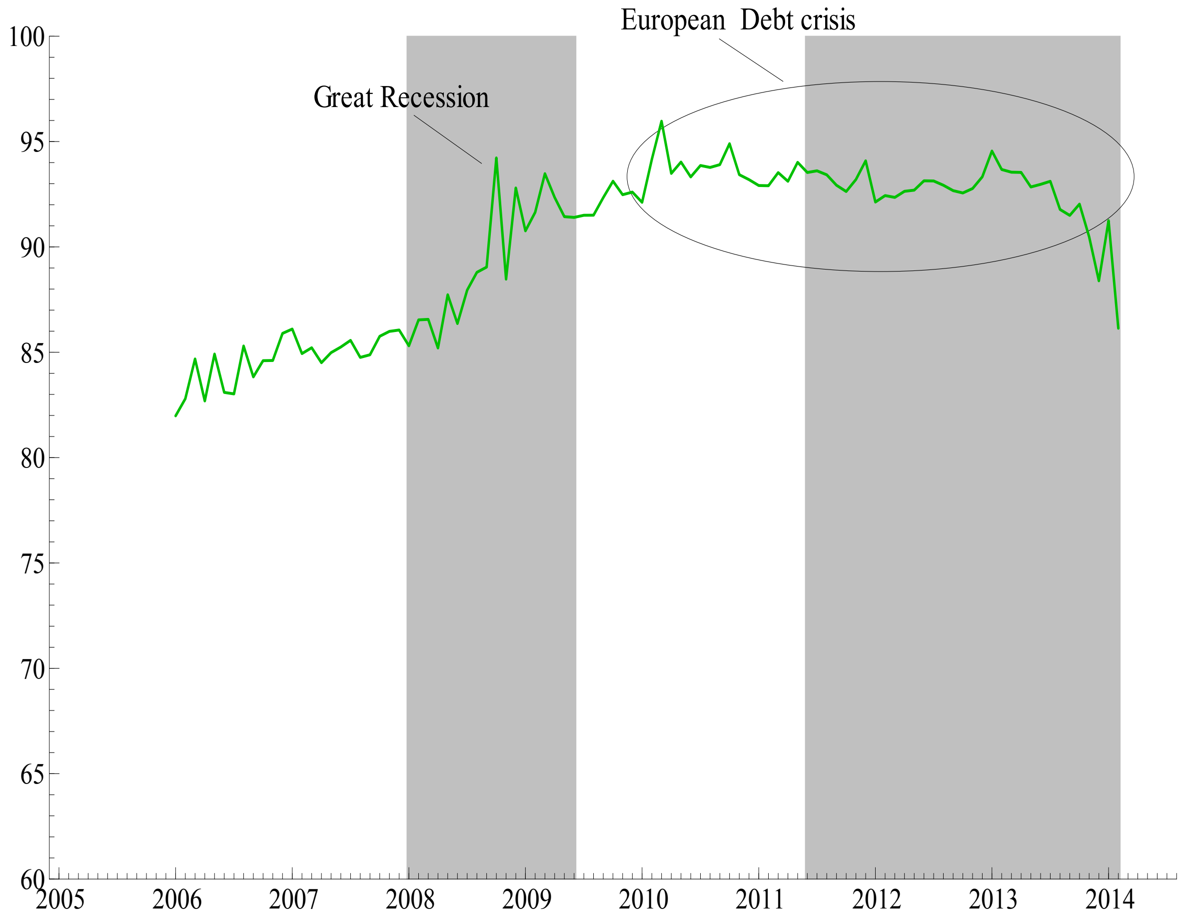
Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 5: Net spillovers of business cycles among Eurozone core, Eurozone periphery and non-EMU



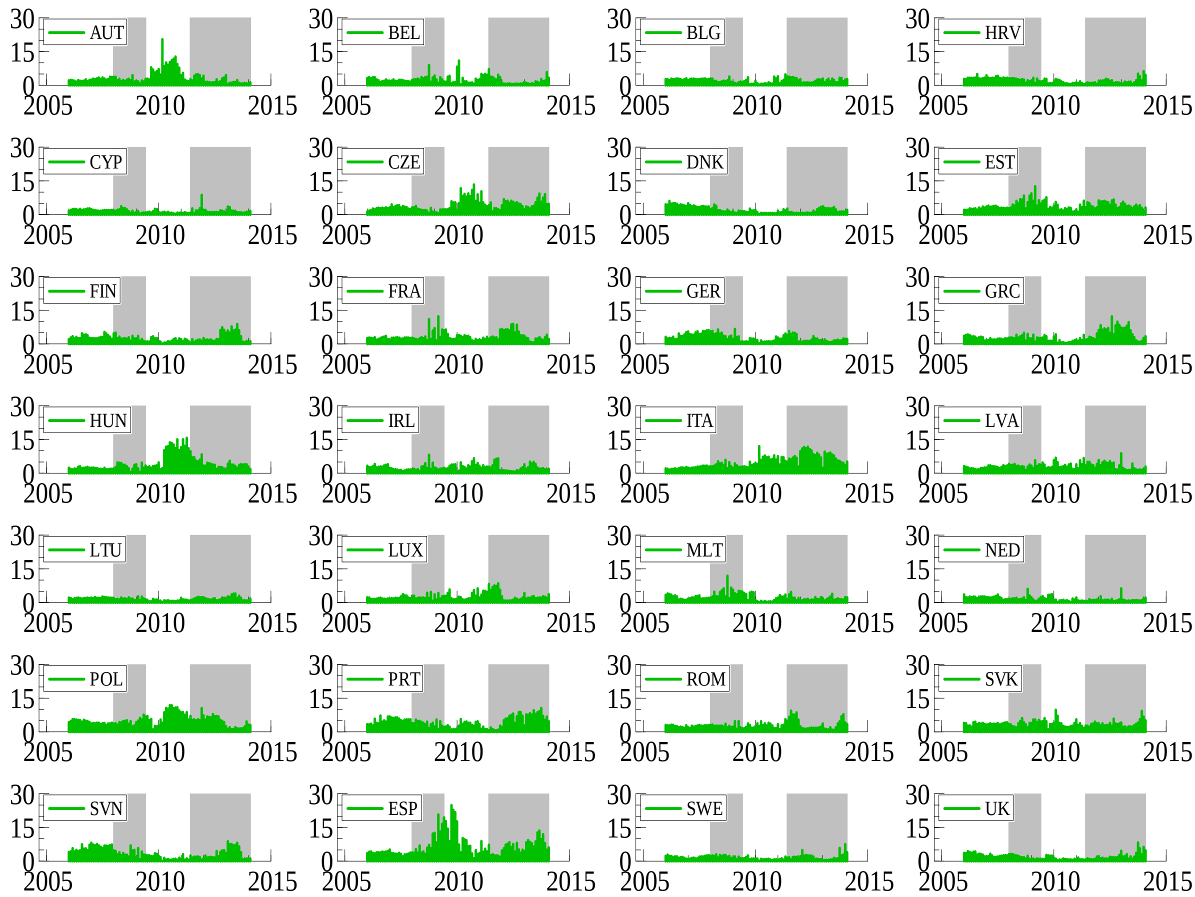
Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 6: Total spillover of business cycles in the EU28



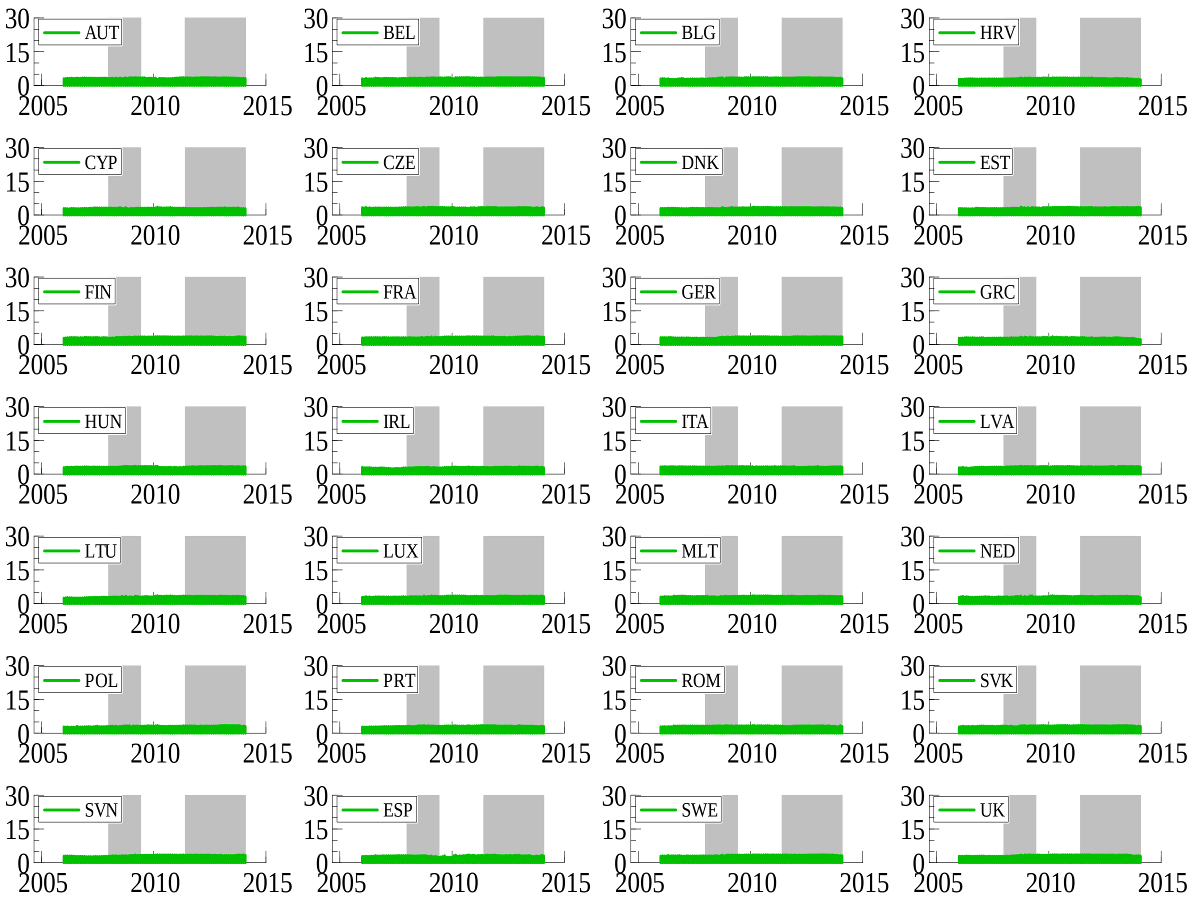
Note: Plot of moving total spillover index estimated using 60-month rolling windows (and hence starting in 2006M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 7: Directional spillovers *FROM* each of the EU28 business cycles to all others



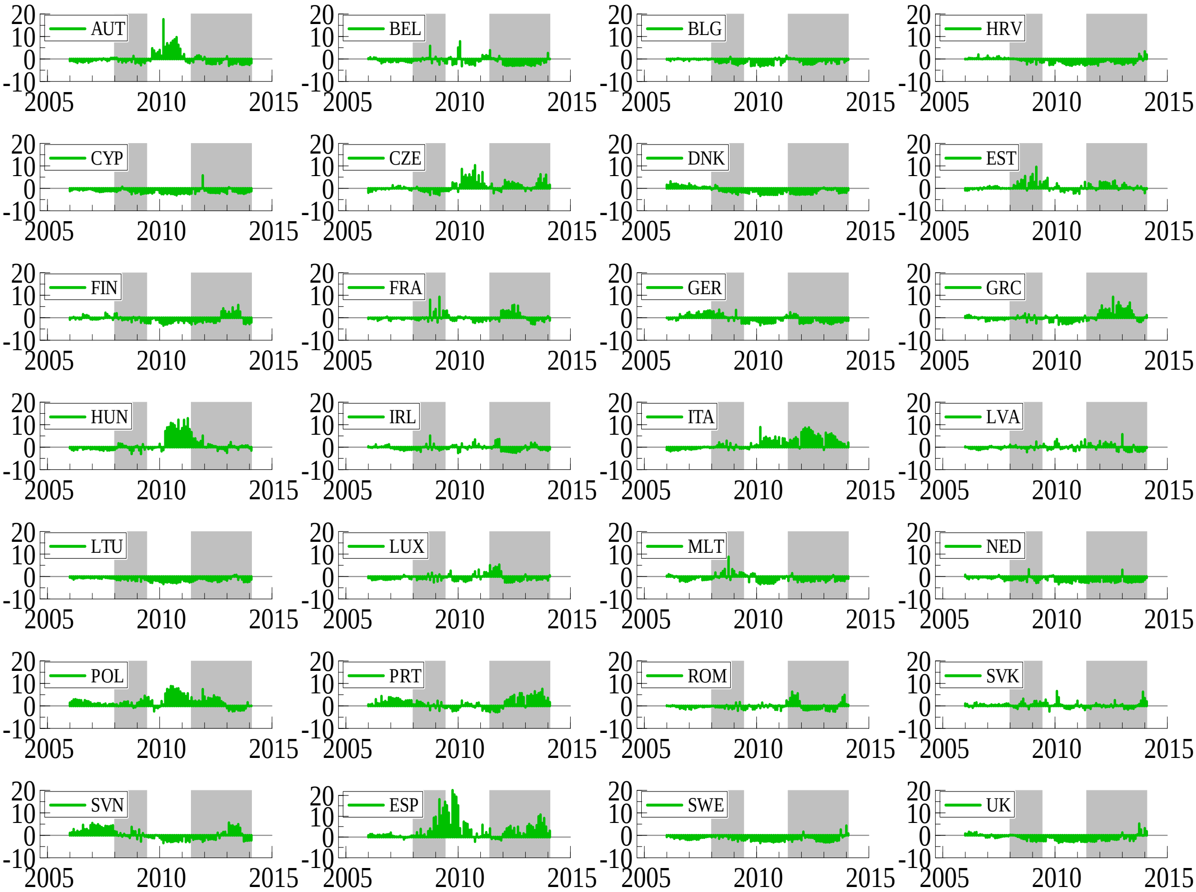
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 2006M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 8: Directional spillovers *TO* each of the EU28 business cycles from all others



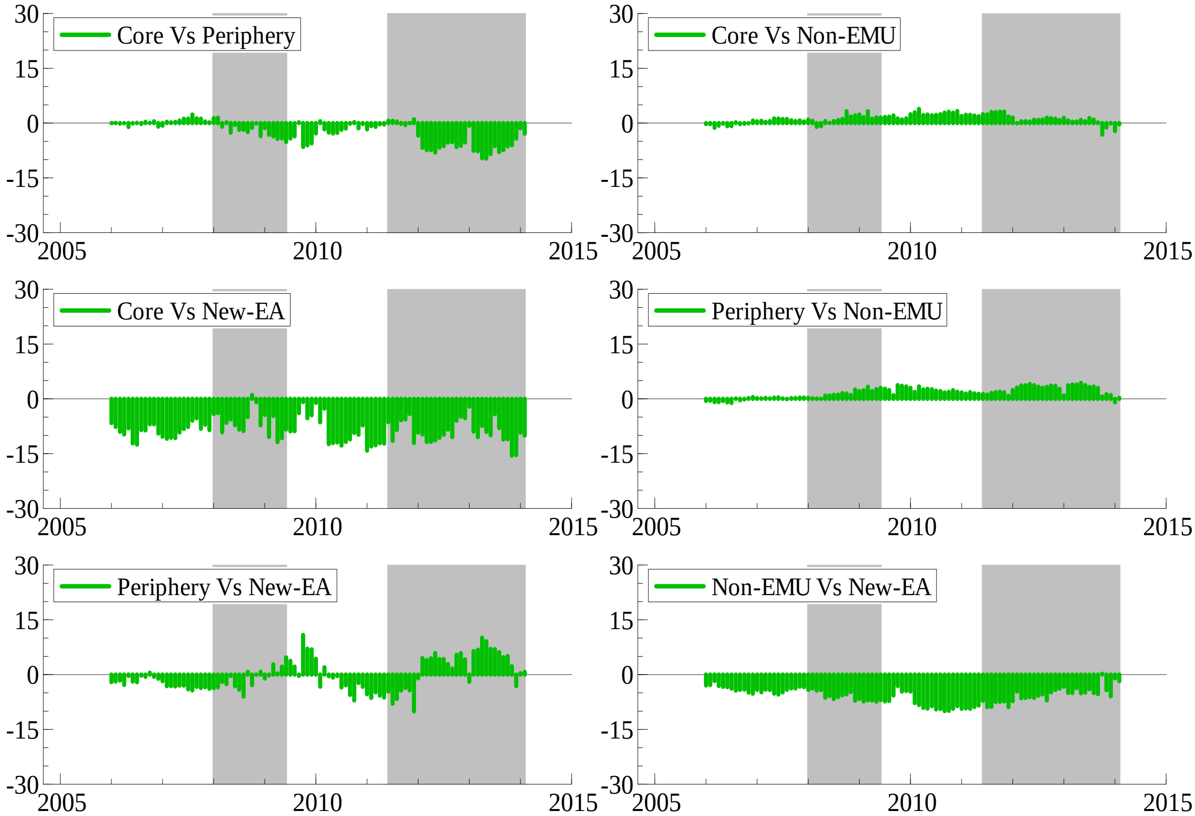
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 2006M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 9: Net spillovers of business cycles in the EU28



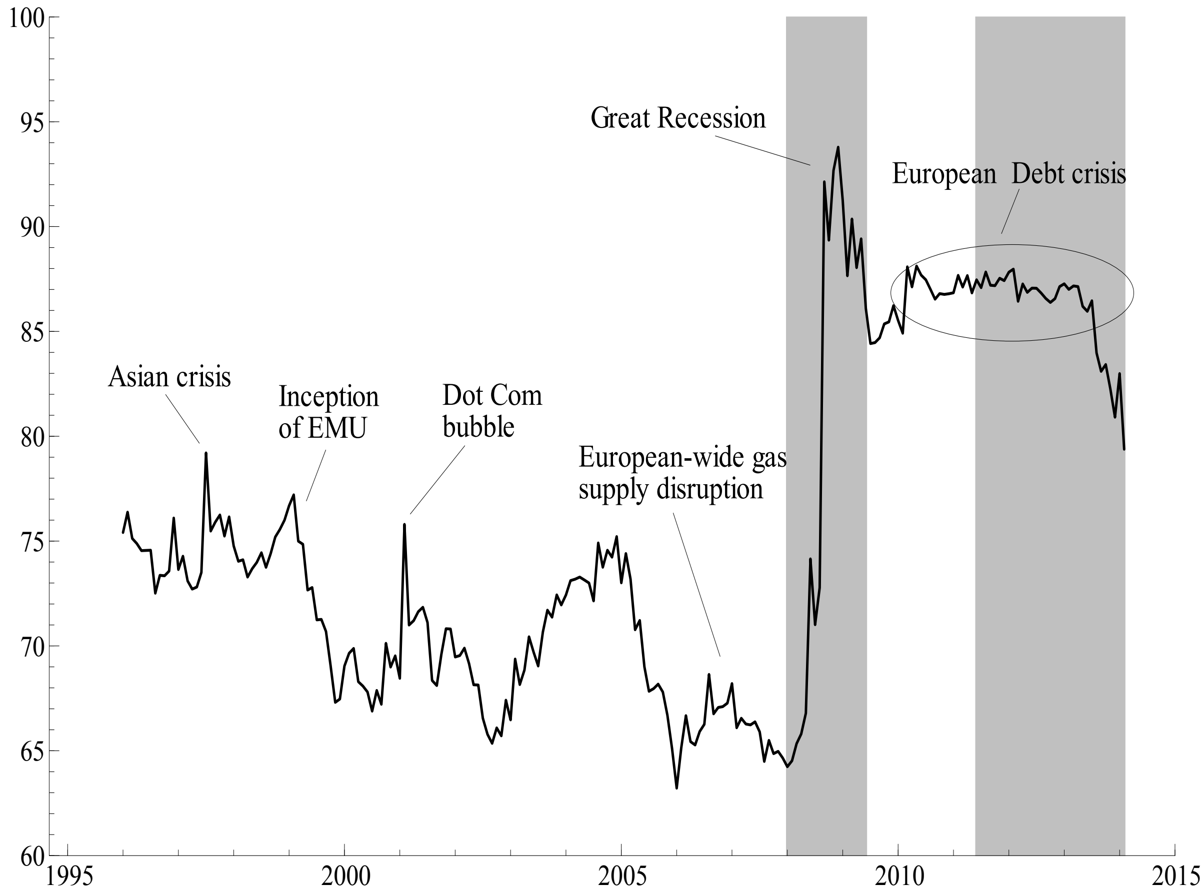
Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 2006M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 10: Net spillovers of business cycles among Eurozone core, Eurozone periphery, non-EMU and new–EA members



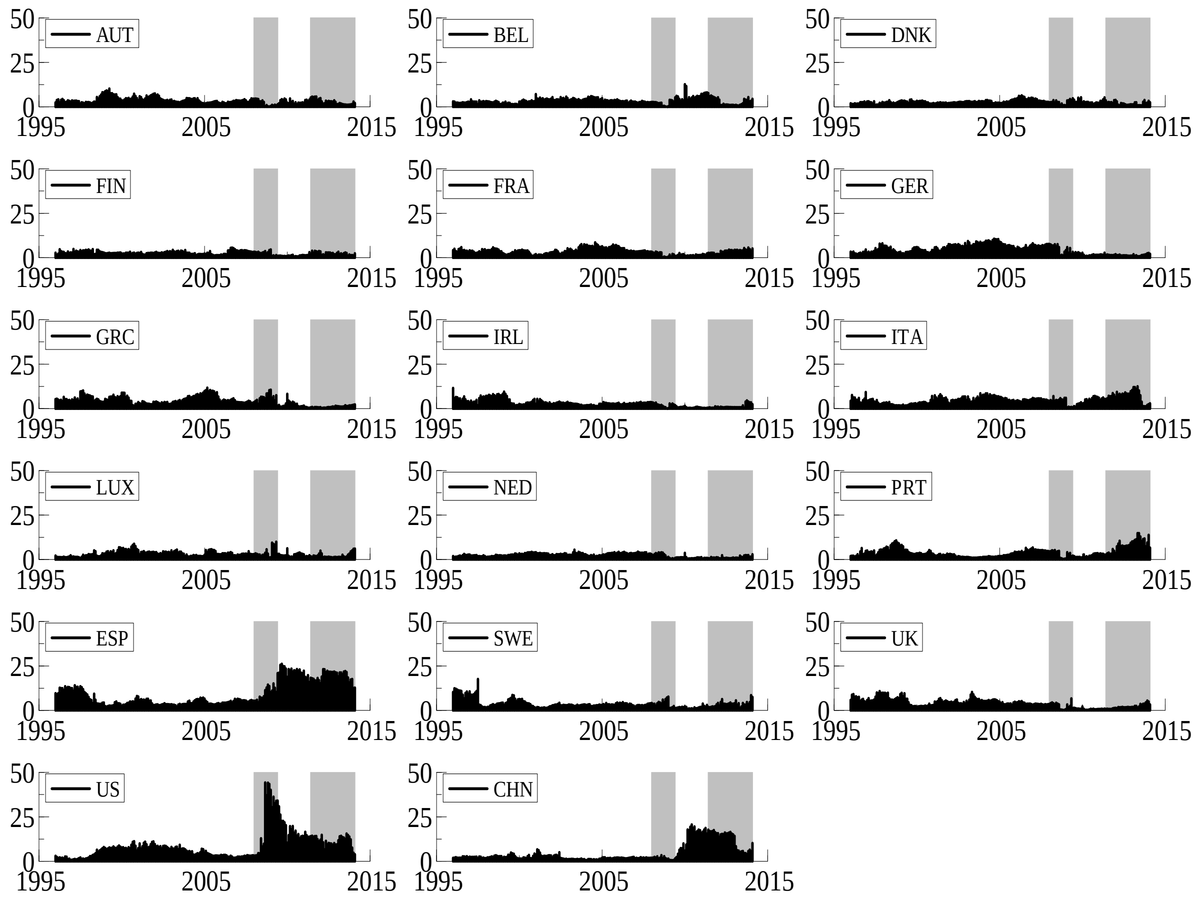
Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 2006M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 11: Total spillover of business cycles in the EU15, US and China



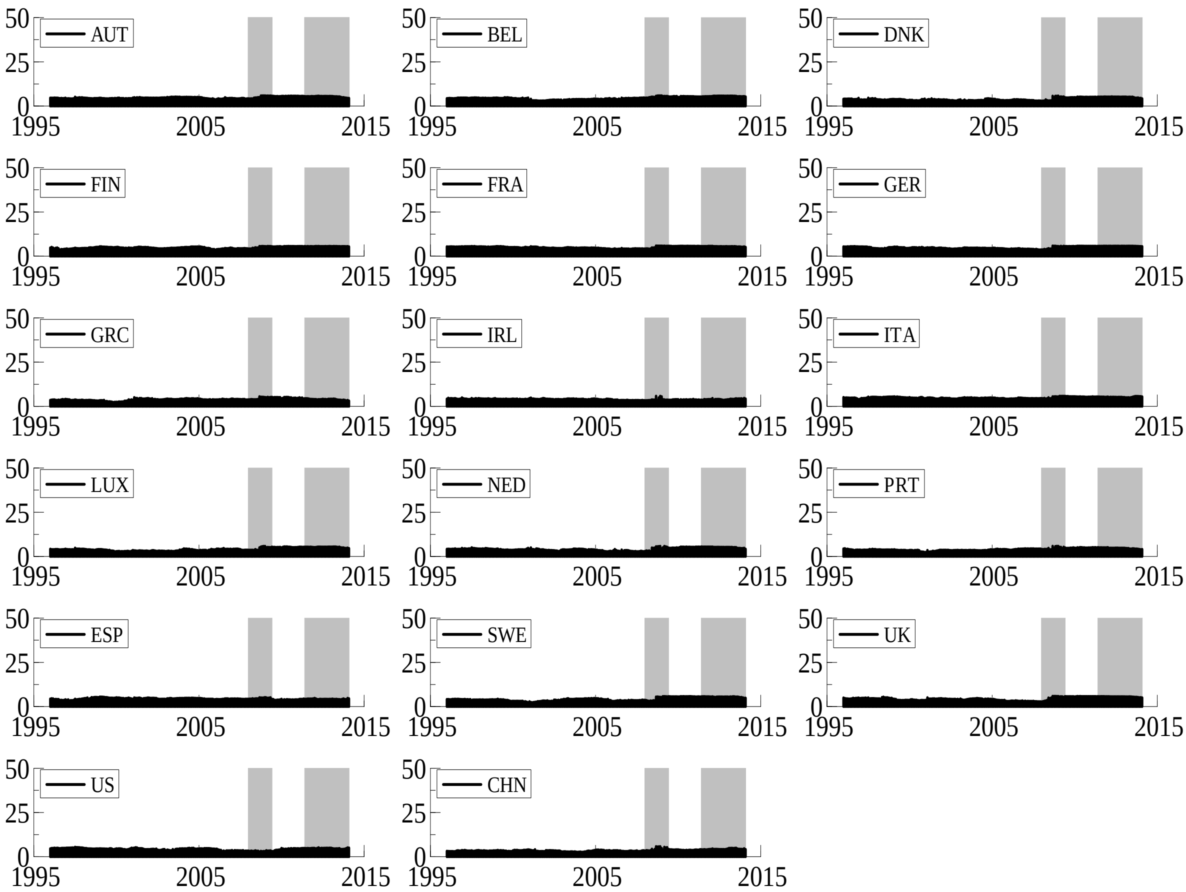
Note: Plot of moving total spillover index estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 12: Directional spillovers *FROM* each of the EU15, US and China business cycles to all others



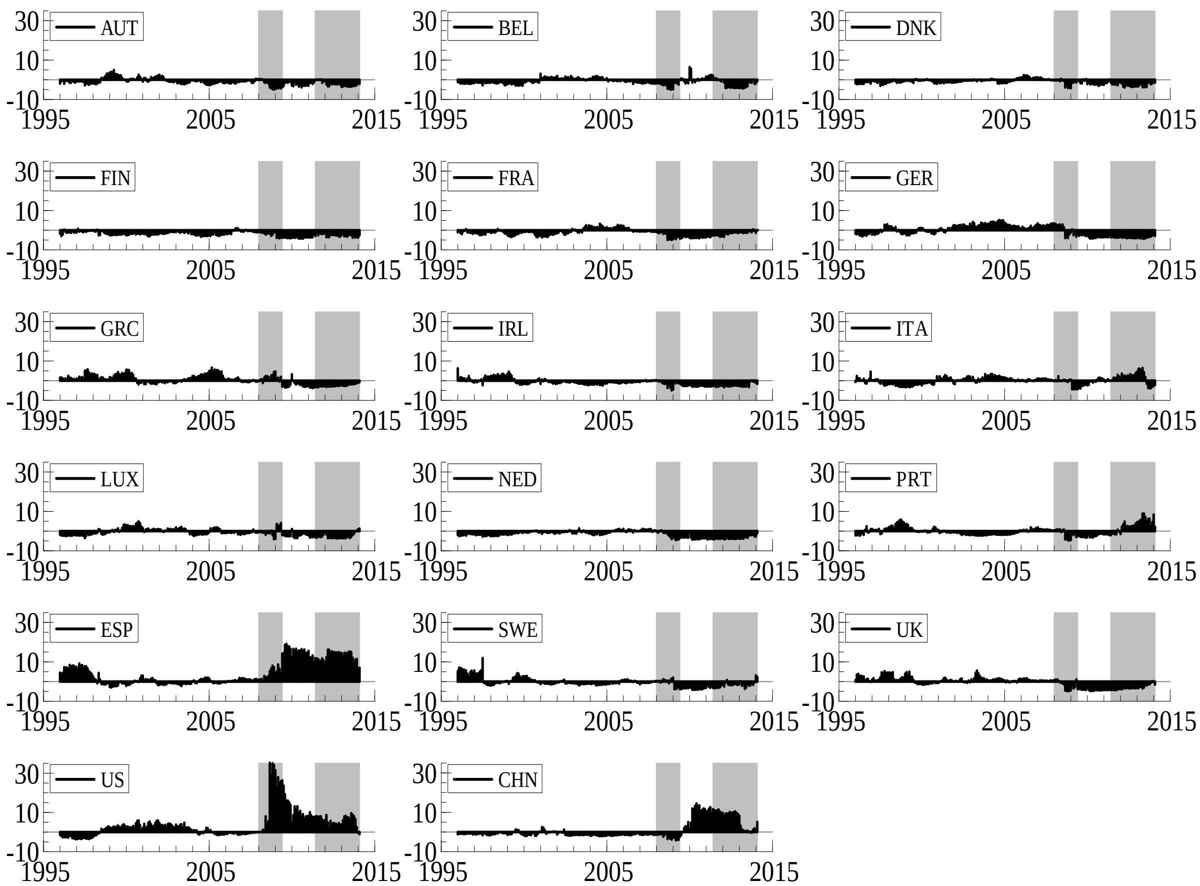
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 13: Directional spillovers *TO* each of the EU15, US and China business cycles from all others



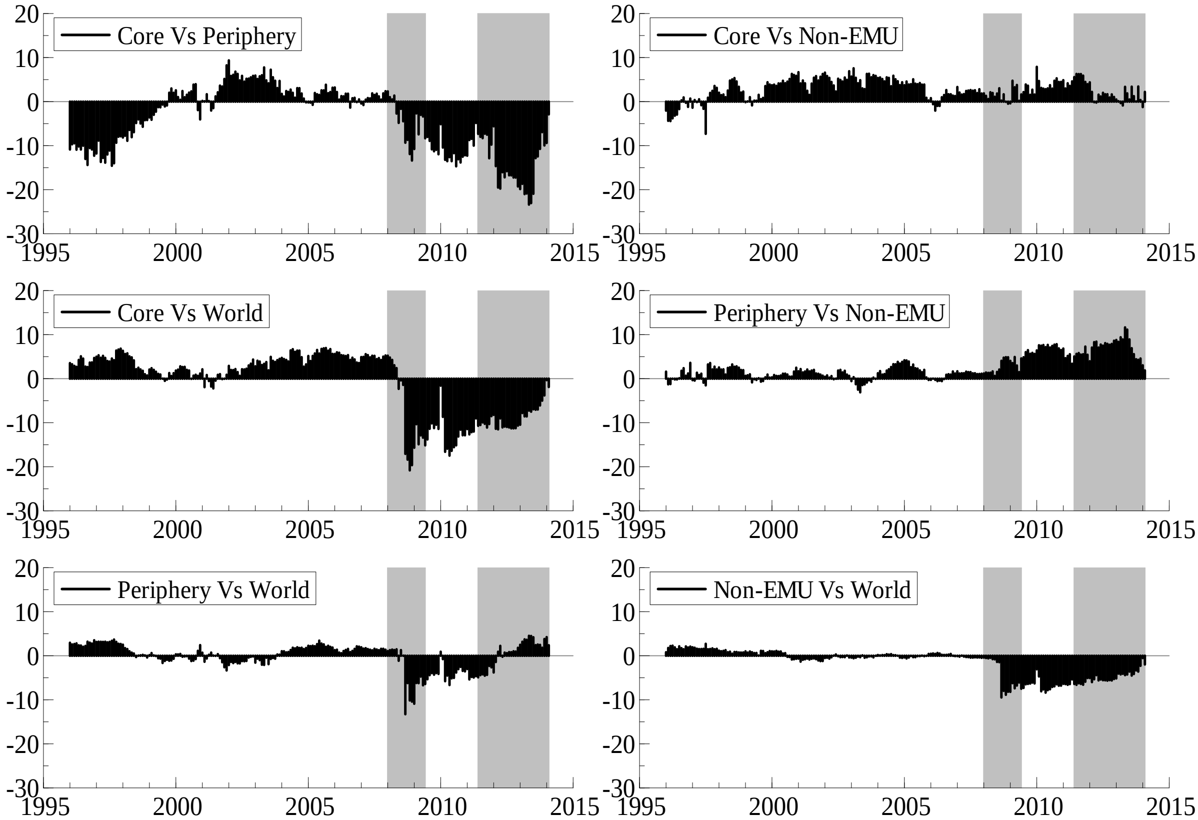
Note: Plot of moving directional spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Figure 14: Net spillovers of business cycles in the EU15, US and China



Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

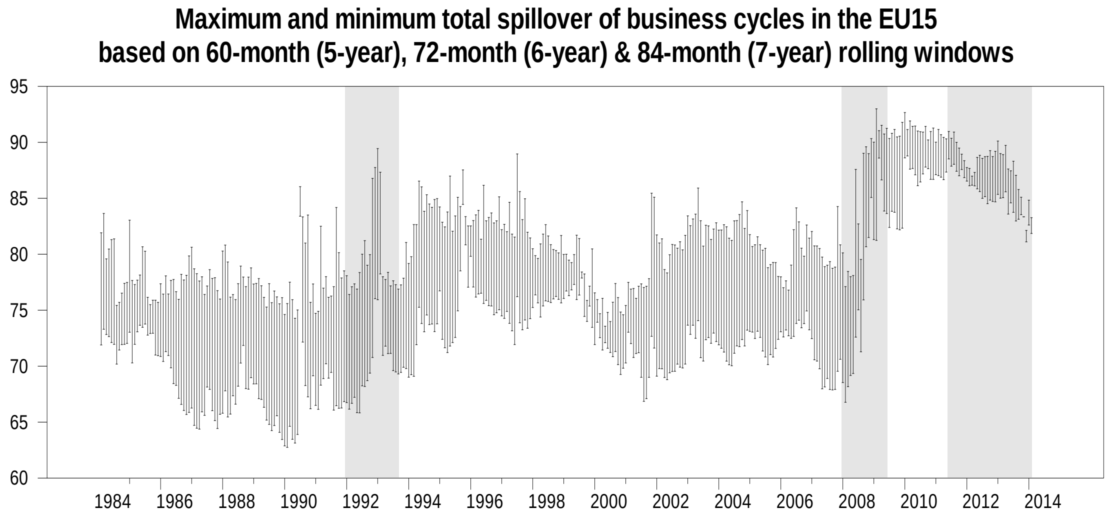
Figure 15: Net spillovers of business cycles among Eurozone core, Eurozone periphery, non–EMU, new-EA members and non-EU (US and China)

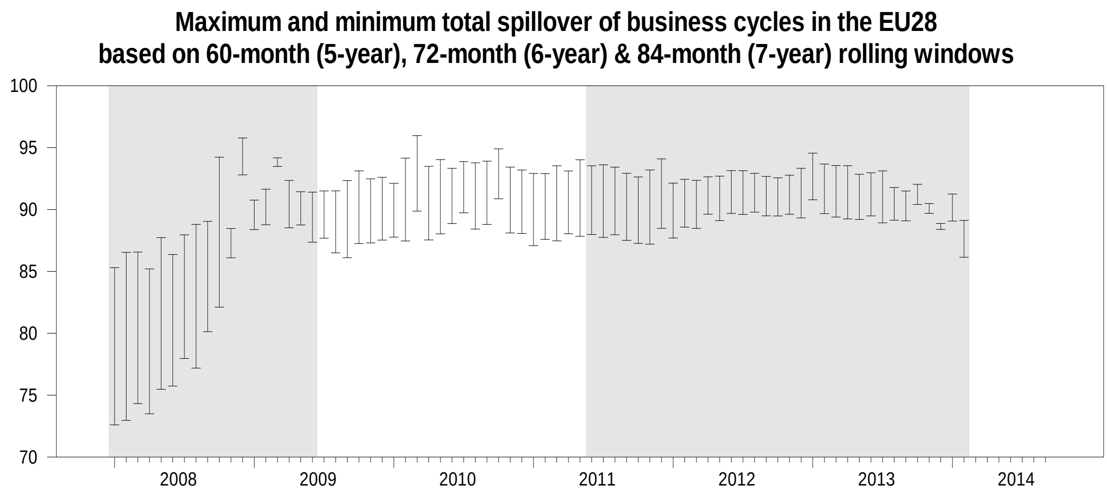


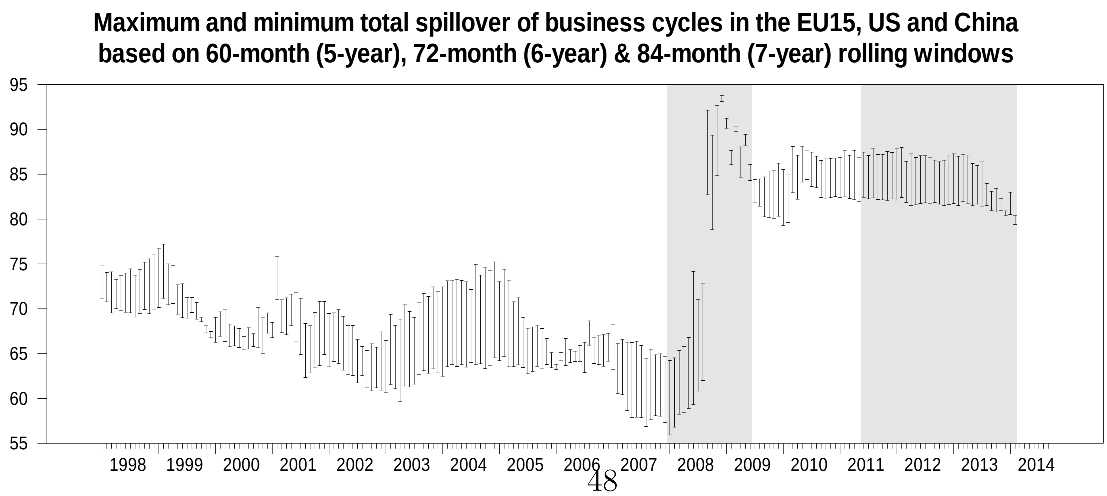
Note: Plot of moving net spillover indices estimated using 60-month rolling windows (and hence starting in 1982M2). Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Appendix

Figure A.1: Total spillover of business cycles in the EU15, EA18, and EU15 and US and China, with alternative rolling window samples







Note: Plot of moving total spillover index estimated using 60-month (5-year), 72-months (6-year) and 84-months (7-year) rolling windows. Grey shaded areas denote EA recessions based on CEPR business cycle dating committee.

Table A.1: Data availability and sources of industrial production

Country	Abbreviation	Data Availability	Source
Austria	AUT	1977M1–2014M6	IMF-IFS
Belgium	BEL	1977M1–2014M6	IMF-IFS
Bulgaria	BLG	2000M1–2014M6	IMF-IFS
Croatia	HRV	1991M1–2014M7	IMF-IFS
Cyprus	CYP	1988M1–2014M6	IMF-IFS
Czech Republic	CZE	1993M1–2014M7	IMF-IFS
Denmark	DNK	1977M1–2014M6	IMF-IFS
Estonia	EST	1998M1–2014M2	IMF-IFS
Finland	FIN	1977M1–2014M7	IMF-IFS
France	FRA	1977M1–2014M6	IMF-IFS
Germany	GER	1977M1–2014M4	IMF-IFS
Greece	GRE	1977M1–2014M7	IMF-IFS
Hungary	HUN	1980M1–2014M7	IMF-IFS
Ireland	IRL	1977M1–2014M4	IMF-IFS
Italy	ITA	1977M1–2014M4	IMF-IFS
Latvia	LVA	1999M1–2014M7	IMF-IFS
Lithuania	LTU	1997M1–2014M7	IMF-IFS
Luxembourg	LUX	1977M1–2014M6	IMF-IFS
Malta	MLT	2000M1–2014M2	IMF-IFS
Netherlands	NED	1977M1–2014M6	IMF-IFS
Poland	POL	1985M1–2014M7	IMF-IFS
Portugal	PRT	1977M1–2014M7	IMF-IFS
Romania	ROM	1991M1–2014M6	IMF-IFS
Slovakia	SVK	1989M1–2014M5	IMF-IFS
Slovenia	SVN	1992M1–2014M6	IMF-IFS
Spain	ESP	1977M1–2014M4	IMF-IFS
Sweden	SWE	1977M1–2014M6	IMF-IFS
United Kingdom	UK	1977M1–2014M7	IMF-IFS
United States	US	1977M1–2014M8	IMF-IFS
China	CHN	1990M1–2014M9	NBS, China

Note: IMF-IFS denotes the International Financial Statistics (IFS) maintained by the International Monetary Fund (IMF). NBS, China stems for National Bureau of Statistics, China.